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Prepared by participants in the 1968 National Defense Education Act Institute on Wood Technology, this syllabus is one of a series of basic outlines designed to aid college level industrial arts instructors in improving and broadening the scope and content of their programs. The guide is divided into three sections, the first of which deals with the types of characteristics of adhesives and includes a discussion of each of the important adhesives. Unit II is concerned with application, clamping, and curing of adhesives, and contains excerpts from articles on glues and adhesives, drawings, and photographs to illustrate the material covered. The third unit is a discussion of adhesive bond tests and the techniques for conducting them. Supplementary materials included are a glossary, a bibliography, and an appendix listing glue and adhesive manufacturers. Related documents are available as VT 007 857, VT 007 859, and VT 007 861. (AW)

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ADHESIVES

A
BASE SYLLABUS
ON
WOOD TECHNOLOGY

Prepared by
INSTITUTE PARTICIPANTS

EASTERN KENTUCKY UNIVERSITY
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FOUNDED 1906
RICHMOND

N.D.E.A. INSTITUTE
for advanced study in
INDUSTRIAL ARTS
June 10 - August 2, 1968

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N.D.E.A. Institute

EASTERN KENTUCKY UNIVERSITY

June 10-August 2, 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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PREFACE

Recently, the area of woodworking has come under much criticism as being too limited in scope and not fully abreast of an advancing technology. Some people have gone as far as to seek its abolition from the industrial arts program in the secondary schools. In reality, however, the importance of woodworking as a phase of industrial arts is probably greater now than ever before. It is conceded, nevertheless, that the scope and content of industrial arts woodworking programs needs to be improved.

Traditionally, a typical woods program is centered upon the use of hand and machine tools with little or no emphasis given to the problem of familiarizing students with technical knowledge of the material itself.

To assist in the upgrading of present programs, students and teachers should, in addition to the use of wood as lumber, be made aware of the various properties of wood and wood products. Of equal importance is a knowledge of new processes and materials used in conjunction with the fabrication, manufacture, and application of wood and wood-related products.

The purpose of the NDEA Institute in Wood Technology held at Eastern Kentucky University during the period June 10 - August 2, 1968, was to provide college level industrial arts woodworking instructors with the opportunity to receive information in depth which they might use to broaden the scope and content of their programs. To this end, the participants have prepared this series of Basic Outlines which attempt to record their experiences during the period of the institute. The "Base Syllabus" prepared by the participants in the 1967 Wood Technology institute was used as a guide in developing the format of this series.

It is hoped that the material covered herein will be applied to the improvement of each participant's woodworking program and lead their students to a greater understanding of wood and wood products.

Jack A. Luy
Institute Director

ADHESIVES

Introduction

Since the time of the Egyptians adhesives have been used in some manner to join together or fabricate complex useful items from smaller units of similar or dissimilar materials.

Although wood has been glued successfully for several thousand years, the art of gluing owes its present importance to comparatively recent developments. During the past two decades the gluing of wood has become increasingly more important in the conversion of timber into marketable forest products.

One event has figured prominently in the outstanding rise of wood gluing: the development of new adhesives, particularly those of the synthetic resin type which offer durable bonds. An adhesive is a substance that is capable of holding objects together by surface attraction.

Modern adhesives, processes, and techniques vary as widely as the products made. In general, however, it remains true that the quality of a glued joint depends upon the kind of wood and its preparation for use, the details of the gluing process, the types of joints, and the conditioning of the joints.

Essentially the gluing operation consists of only three basic requirements.

The first of these is that the adhesive must "wet" the surface. The "wet" is used here in the same context as it is, for example, when we talk of "wetting" the hands with soap and water. Unless the adhesive gets all the way to the surface and does actually come in contact with it, it is not possible for the adhesive to exert any force on that surface to hold it firmly against another material. This is one of the basic reasons for the caution in all gluing requirements, that the surfaces should be clean. It can easily be seen that any dust or dirt on a surface may serve to keep the adhesive from actually coming in contact with the surface.

On the subject of glue transfer, it may be well to mention that some glues are applied to one surface only and they must physically transfer to the opposite face. This is called a single spread. Under some conditions, the glue might skin over after it is applied and before the parts are assembled. Because of the formation of the "skin", and the effect that it has when the surfaces are brought together, the glue is not able to properly wet the opposite face, and a poor joint would result.

Therefore, in many cases applying glue to both surfaces in thin films is necessary to properly wet them. This is called a double spread.

The second major requirement for all adhesive work is that there must be an actual attraction between the adhesive and the surface being bonded. The bonding of wood with an adhesive is a phenomenon of adhesion, the joining of two different bodies of matter. In this process, two types of adhesion are in force, mechanical adhesion and specific adhesion. The possibility is not ruled out that forces of specific adhesion also play a role in mechanical adhesion. For example, the strength of the anchorage of the hardened tentacles of glue in the wood may be traceable, in part, at least, to specific adhesion.

It is now generally agreed that specific adhesion is responsible for most of the strength of strongly bonded wood joints, whereas mechanical adhesion accounts for but a small fraction of the strength. The following is an explanation of these two types of adhesion:

Mechanical adhesion: The mechanism of mechanical adhesion is explained by assuming that the adhesive, while still in liquid form and hence mobile, penetrates into the cell cavities of wood. After it solidifies, the strength of the bond is due, at least in part, to the interlocking of the two solids, the wood and the tentacles of the adhesives embedded in the wood.

Specific adhesion: This is explained on the basis of molecular or atomic attraction between the adhesive and the wood surface. Such adhesion does not require the penetration of a certain amount of the adhesive into the wood.

The third major requirement for an adhesive is that it changes from a liquid to a strong solid substance able to retain that strength for the planned service life of the parts that it bonds together. This is an extremely important function, possibly the most important of the three, though if the adhesive neither wets the surface nor is attracted to a surface, it would matter very little whether it cured to a strong hard substance or not.

In general, woodworking adhesives can be divided into two main groups: (1) those formulated from materials of natural origin, and (2) those made of synthetic materials. A discussion of each of the important adhesives follows in Unit I.

Unit II is concerned with application, clamping and curing of adhesives; while Unit III is a discussion of adhesive bond tests and the techniques for conducting them.

UNIT I

TYPES OF ADHESIVES AND THEIR CHARACTERISTICS

Introduction

There are quite a number of adhesives available today for wood bonding purposes. These represent a wide variety of compositions, some of which have been especially formulated to do a specific job of gluing. In order to better describe these products they are arbitrarily divided into two broad classifications: Natural and Synthetic adhesives.

Natural adhesives are characterized by the fact that their prime constituent is derived directly or indirectly from natural material. Included in this group are animal, casein and blood products.

Synthetic adhesives are manufactured from synthetic raw materials to produce compositions that perform reliably in woodworking applications. These products can be divided into two broad groups of thermosetting and thermoplastic types.

Thermosetting resins may be defined as those which are converted by catalysts or heat to an infusable and insoluble state. They resist moisture and heat conditions rather well although some adhesive types are much better in this respect than others in the group.

Thermoplastic adhesives are generally defined as those which become plastic after cure when subjected to heat. That is, they deform under stress and may exhibit creep characteristics detrimental to a good bond.

I. Animal and fish glue--animal adhesives are derived principally from hide and bone materials of animals. Fish glue is compounded from the heads, bones, skins and bladders of fish.

A. Trade names - Franklin Liquid Glue is a common brand of animal glue in ready-to-use liquid form. LePages Liquid Glue is an example of a fish glue.

B. Form and mixing process - Animal glue is purchased in dry, granular form, mixed with cold water, soaked and then heated to 145°F. Liquid forms, including fish glue, are to be used directly from the container.

C. Chief use - Animal adhesives are still used to a degree in assembly, edge gluing and laminating though their use is declining in favor of synthetic resins. Fish glues seem to have been replaced almost entirely by other types.

D. Clamping and curing - Clamp at room temperature and allow approximately 6 hours curing time for cold liquid. Less time may be required for the hot mix type.

E. Adhesion Characteristics - Animal glues are very durable for interior use though they rate poorly in water and heat resistance. Fish glues are generally less strong than dry animal glues when the latter are mixed and applied properly.

II. Blood adhesive -- derived from the blood of swine and cattle.

A. Form and mixing process - Blood adhesives come in powder form and are mixed with water, alkali, etc.

B. Chief use - Used primarily in the manufacture of interior grades of softwood (fir, pine, etc) plywood.

C. Clamping and curing - Normally used with hot press operations, fast curing.

D. Adhesion characteristics - Will bridge slight gaps. Glue line is susceptible to fungus attack under certain humidity conditions.

III. Casein glue--A dry blend of raw casein (dried mild curd) and alkaline chemicals. The oldest of water resistant glues.

A. Trade names - A number of manufacturers produce casein glue. Most use the word Casein on the label.

B. Form and mixing process - supplied in dry form and mixed with water at the time of use.

C. Chief uses - Used widely in structural timber laminating, laminating of flush doors and to some degree in assembly and edge banding.

D. Clamping and curing - Clamp at room temperature (see characteristics re: temperatures). Low alkaline mixes are slow curing.

E. Adhesion characteristics - While not truly waterproof, casein glue is highly water resistant. Unique in its ability to bond at lower temperatures (as low as 40°F.). Will accept a variation (2 to 18%) in the moisture content of the adherends. Possesses good gap filling characteristics. Casein glues are susceptable to mold or fungi attack though preservatives are sometimes added to minimize such deterioration. High alkaline content mixes tend to stain woods, particularly oak.

I V. Contact cement --Compounded of neoprene rubber and volatile solvents.

A. Trade names - The words Contact Cement or Contact Adhesive invariably appear on the label.

B. Form and mixing process - Contact cements are applied directly from the container with no mixing required. Lacquer thinner can usually be used for clean-up and to a moderate degree for thinning. Water emulsion types are available requiring only water for clean-up.

C. Chief use - Plastic laminates to wood, particleboard, etc. works well for natural wood veneers if the adhesive coat is free of lumps. May be used successfully on leather where a flexible bond is required. May not be used near sparks or flame except non-flammable water emulsion types.

D. Clamping and curing - Both adherends are coated (bare wood may require a second coating) and allowed to dry until wet tack is gone. Adherends are then placed together and bond is made by momentary pressure applied over entire surface. Pinch rolls, forceful rolling with a brayer or tapping with a hammer over a block of wood are acceptable methods of pressure application. Open assembly time is a restriction in industry.

E. Adhesion characteristics - Applicable only to larger joint areas due to tendency toward cold creep under stress. Generally low in heat resistance.

V. Epoxy Resin Adhesive--A reaction product of epichlorohydrin with a phenol body resulting in a 100% solids liquid system.

A. Trade names - The words Epoxy or Epoxy Resin invariably appear on the label. Identification may be further verified by the presence of two equal size containers--one containing resin, the other catalyst. These are usually packaged together for sale as one unit.

B. Form and Mixing process - Both resin and catalyst are in liquid form and are mixed together at time of application. Some instances are known where one adherend is coated with resin, the other adherend coated with the catalyst thereby bypassing the mixing step and giving a long open assembly time.

C. Chief use - Epoxy adhesives have less than perfect bonds in joining wood to wood. They are applied generally where there are no-shrink properties. Their ability to join dissimilar materials offset their very high cost.

D. Clamping and curing - Application is generally heavy and in many instances, clamping can be omitted so long as the adherents are kept immobile. Heat will speed curing time.

E. Adhesion characteristics - Due to their 100% solids composition, epoxies have absolutely no shrinkage and are unchallenged in gap-filling properties. They have high heat resistance and will successfully adhere materials not generally regarded as practical for gluing such as metal, ceramics, glass, plastics, etc.

VI. Melamine resin adhesive--A condensation, reaction product of melamine chemical and formaldehyde. Co-polymers are produced with urea to yield melamine urea formaldehyde adhesive resins.

A. Trade names - M-3 Melamine Resin Glue, a melamine resin glue by National Casein; Casein; Cascomel MU-660, a high ratio melamine/urea adhesive; Cascomel MU-206, a melamine/urea adhesive in powder form requiring addition of water only; Cascomel MU-658, a melamine/urea adhesive used with separate catalyst. Cascomel series are supplied by Borden, Inc. American Cyanamid Company offers a similar series labeled Melurac.

B. Form and mixing process - Usually in powder form to which water and in some cases, a catalyst is added.

C. Chief uses - Unmodified melamine adhesives are used in straight and curved hardwood plywood laminating where a waterproof bond is required. Urea/melamine compounds are used where the melamine component adds water resistance desirable for scarf jointing, finger jointing, railroad decking and parquet flooring.

D. Clamping and curing - Heat either in the form of hot press (approximately 250°F.) or dielectric (radio frequency) application is required.

E. Adhesion characteristics - Melamine adhesiaes are waterproof and are preferred over phenol and resorcinol resins where the lighter glue line color of the melamine resins is an advantage. Melamine/Urea combinations are less expensive and have increased durability over straight urea in direct proportion to the percentage of melamine content.

VI I. Phenol resin adhesives--A condensation reaction product of phenol and formaldehyde. May be combined with resorcinal to make Phenol/Resorcinal adhesives.

A. Trade names - Cascophen series by Borden, Inc. include Phenol and phenol/resorcinol resin adhesives. (exception: Cascophen RS-216 is an unmodified resorcinal resin glue. All others in Cascophen series are phenol or phenol/resorcinal combinations).

B. Form and mixing process - Available in either liquid or powder form (powder phenol forms keep from 4 to 8 months, liquid forms are stable for only 1 to 3 months at 70°F.) Phenol resins may be mixed with shell flour added as a filler. Phenol/resorcinol blends are mixed with a powdered catalyst.

C. Chief uses - Phenol resins require heat to cure and their use is therefore generally confined to the manufacture of flat panels. Accordingly, the greatest application has been in the softwood plywood industry in producing exterior grade sheathing.

D. Clamping and curing - Phenol resins require hot press applications of from 250 to 300° F. Phenol/resorcinol resins may be cured at room temperature though higher phenol content mixes need heat of from 150 to 180° F. to yield optimum water resistance.

E. Adhesion characteristics - Phenol resins produce the most durable wood-to-wood bonds known. Phenol/resorcinol blends offer comparable durability at reduced cost though curing is somewhat more difficult.

VIII. Polyvinyl resin adhesive--three major types are now on the market.

A. Polyvinyl - Aliphatic resin adhesive - A modified PVA (polyvinyl acetate) resin adhesive having generally superior heat resistance.

1. Trade names - Titebond regular, Titebond Slow Set (offering increased assembly time), Titebond Gold Seal (faster setting), Titebond #50 (very fast setting), and Titebond Imperial (higher in heat resistance) are aliphatic resin adhesives available from the Franklin Glue Co.

2. Form and mixing process - No mixing required.

3. Chief uses - Same as Polyvinyl acetate resins.

4. Clamping and curing - Clamp at room temperature for a slightly longer time than regular polyvinyl. Responds well under RF gluing systems.

5. Adhesion characteristics - Under normal conditions, aliphatic resin glue shows no advantage over PVA though it is substantially more resistant to failure under higher heat exposure (up to 250°F.). Other characteristics under PVA apply.

B. Polyvinyl resin adhesive--three major types are now on the market.

1. Trade names - Elmer's Glue-all, Cascorez--consumer and industrial names respectively by Borden, Inc.; Assembly Glue #65 by Franklin Glue Co.; Welwood Presto-Set by U.S. Plywood; #5000 & #5005 Polyvinyl Joint and Assembly Glue National Casein; Wilhold White Glue by Wilhold Glues, Inc. are commonly found brands.

2. Form and mixing process - No mixing required.

3. Chief uses - Edge gluing, assembly gluing, panel to frame gluing, flush doors, etc.

4. Clamping and curing - Clamp at room temperature 30 minutes minimum (most grades). Will work satisfactorily with dielectric (RF) methods.

5. Adhesion characteristics - Fairly low in water resistance and, as would be expected of a thermoplastic adhesive, is fairly low in heat resistance, susceptable to creep under load. Glue line is more or less transparent. Fairly good gap-filling properties.

C. Thermosetting Polyvinyl Resin Adhesive--A catalyzed variation of polyvinyl resin adhesive exhibiting far superior heat and water resistance.

1. Trade names - Mulitbond by Franklin Glue Co., Cascorez WB-900 by Borden, Inc.

2. Form and mixing process - Liquid resin and catalyst must be mixed carefully according to manufacturer's recommendations (usually 5 to 6% catalyst by weight).

3. Chief uses - Use is somewhat restricted due to higher cost and care and accuracy required in mixing. Used for adhering plastic forms and general wood bonding.

4. Clamping and curing - Requires intimate contact of adherents and uses higher clamp pressures (up to 200 psi. for hardwoods). Requires 24 hours clamp time at 72°F.; 2 1/2 hours at 100°F.; 3 minutes at 300°F. Certain brands indicate substantially less clamp time. Responds well to RF gluing systems.

5. Adhesion characteristics - Fully waterproof, with some modification, will bond to metal. Prior to setting, materials can be cleaned up with hot water.

IX. Resorcinol resin adhesive--A condensation, reaction product of resorcinol chemical and formaldehyde. One of the best know and most readily available waterproof adhesives.

A. Trade names - Elmer's Waterproof Glue, Cascophen RS-216--consumer and industrial labels, respectively by Borden, Inc. R-3 Resorcinol Resin Glue, by National Casein; Weldwood Resorcinol Glue, by U.S. Plywood; Wilhold Waterproof Resorcinol Glue, by Wilhold Glues, Inc.

B. Form and mixing process - Two mixtures are available; unmodified or straight resorcinol (such as those named above) and phenol/resorcinol mixtures (see under Phenol resin adhesives). All resins are in the form of a wine-colored liquid and a formaldehyde-donor type of powdered catalyst is added at the time of use.

C. Chief use - Exterior grade laminated timbers, trusses, marine-grade plywood. Cost is relatively high.

D. Clamping and curing - Clamp and cure at room temperature or slightly higher in the case of phenol blends. Specific compounds can be RF cured.

E. Adhesion characteristics - Fully waterproof bond can be obtained without heat curing equipment. Dark red glue line may be a disadvantage in some cases.

X. Urea Resin Adhesive--A condensation, reaction product of two low-cost materials: urea and formaldehyde. Urea resin adhesives are the most versatile and economical thermosetting resins available.

A. Trade names - Weldwood Plastic Resin Glue, By U. S. Plywood; Willhold Plastic Resin Glue by Wilhold Glues, Inc.; Urac Resin series, by American Cyanimid; Cascamite and Casco-Resin series, by Borden, Inc.; "DR" Powdered Urea Resin Glue and 750 Liquid Urea Resin Glue are two offered by National Casein.

B. Form and mixing process - Powder forms are normally mixed with water only--liquid forms usually are mixed with a powdered catalyst.

C. Chief use - Interior laminations, assembly, interior hardwood plywood. Particle board manufacturers are the largest single users of the liquid type of Urea Resin adhesive.

D. Clamping and curing - Either hot or cold press techniques may be used with powder forms, hot press is generally preferred with liquid forms. Generally high pressures required.

E. Adhesion characteristics - Produces a rigid but brittle glue line with no staining. Glue bond is moderately water resistant, satisfactory only for gluing wood to wood. Poor gap filling characteristics. Modification with furfural alcohol improves gap filling characteristics.

I.X. Hot melt adhesives--Generally comprised of resin derivatives and synthetic polymers such as polyethylene and polyvinyl acetate co-polymers.

A. Trade names - The major hot melt adhesive system presently available commercially is the "Thermogrip" glue gun and adhesives supplied by the B. B. Chemical Division of United Shoe Machinery Corporation.

B. Form and mixing process - Commercially, hot melt glue comes in stick form designed especially for the glue gun. Industrially, the glue is supplied in chunk form. In either case, no mixing is required, only heating.

C. Clamping and curing - The glue adheres as it cools following hot application. Minimum pressures are required.

D. Chief use - Edge banding of thin veneers and plastic laminates, reinforcing corner blocks where only momentary pressure can be applied are major uses.

E. Adhesion characteristics - Due to their thermoplastic nature, hot melt adhesives are low in heat resistance and most will not withstand long periods of moisture. Where these conditions will not prevail, the quick set characteristics are encouraging and promise widespread application for hot melt adhesives.

Characteristics of

Adhesive Type	Form	Mixing Procedure	Color Glue Line	Chief Application and Use	Advantages
Animal Glue (Dry)	Granular	Mix with water, soak, heat to 145° F.	Tan-Brown	Assembly, edge gluing and laminating	Very durable for interior use, quick setting
Animal Glue (Liquid)	Liquid	None	Off-white-brown	Assembly, edge gluing and laminating	Very durable for interior use, quick setting
Blood	Powder	Mix with water, alkali, etc.	Dark red	Fir plywood	Fast curing, tolerant of rough veneers
Casein	Powder	Mix with water	Cream	Laminated timbers, doors, assembly edge gluing	True cold setting (down to 39°F.), tough, resilient, excellent bond to wood, gap filling
Contact Cement	Liquid	None	Yellow-tan, red	Plastic & similar laminating	Quick bond, pressure unnecessary; shock resistant, moisture proof, very convenient
Epoxy Resin	Liquid	Mix with liquid catalyst	Varies	Special applications	Capable of wide modification, outstanding in gap filling, poly-functional
Melamine Resin	Powder	Mix with water and shell flour	Colorless-tan	Hardwood plywood	Permanent except for most severe uses
Melamine Urea Resin	Powder or Liquid	If powdered type, mix with water, catalyst optional	White-tan	Tapeless splicing, hardwood plywood, edge and end-glued lumber	Moderate cost, excellent durability for severe interior use
Phenol Resin	Liquid or Powder	Usually mixed with shell flour filler	Brown	Fir plywood	Durable bond, waterproof
Phenol-Resorcinol Resin	Liquid	Mix with powdered catalyst	Dark red	Laminated timbers, sandwich panels, general bonding, boats, skis	Moderate cost with no loss in durabality, increases craze resistance, permanent even for exterior uses, including marine
Polyvinyl (Aliphatic Resins)	Liquid	None	Yellowish or whitish transparent	Assembly gluing, laminating, edge gluing	Colorless, odorless, quick setting, no fire hazard, economical, sets down to chalk point circa 60°F., wide variety of adherents, except metal
Resorcinol Resin	Liquid	Mix with powdered catalyst	Dark red	Laminated timbers, trusses, marine structure, high pressure laminates	Permanent including marine, sets down to 70°F.
Soybean	Powder	Mix with water, alkali, etc.	Light	Fir Plywood	Will bond cold press, tolerant of roughness
Urea Powder	Powder	Mix with water	Tan	Lumber & hardwood plywood, assembly gluing	Economical, ideal color, sets down to 70°F., reliable for indoor use
Urea Liquid	Liquid	Mix with powdered catalyst—fillers, extenders optional	White-tan	Hardwood plywood, particleboard, assembly gluing	Economical, ideal color, sets down to 70°F., reliable for indoor use
Urea—Furfural Modified	Liquid	Mix with powdered catalyst	Brown	Miscellaneous assembly, high pressure laminates	Less gap sensitive than straight urea, especially suited to bonding high pressure plastic to plywood
Vegetable Starch	Liquid or Powder	Mix with water (powder) or use liquid as received	Tan-Brown	Hardwood plywood, assembly gluing	New ones may have unusual properties, older ones for veneering with delicate or fragile, highly figured wood
Vinyl Polymer Thermosetting	Liquid	Catalyst, 5% by Weight	Transluscent straw	Plastic foams, board products, general wood bonding	Cold setting, weather resistant, with some modification will bond to metal, easy hot water clean-up

Common Glues

Disadvantages	Service Durability	Clamping or Processing Conditions	Approx. Shelf & Working Life—Normal Conditions	Normal Spread wet wt./M sq. ft. Single Glue Line	Comparative Cost	Tendency To Stain
Poor water and heat resistance	Interior use	Clamp at room temperature	Indefinite dry one day mixed	60-80 lbs.	Moderate	No
Poor water and heat resistance	Interior use	Clamp at room temperature	3-6 mos.	35-45 lbs.	Moderate	No
Destroyed by fungus and bacteria under certain conditions, very dark color, requires special handling	Water resistant	Hot press 230-280°F.	Indefinite dry 4-12 hours mixed	35-50 lbs.	Low	Yes
Mold susceptible, slow curing, may stain, hard on tools, expensive	Water resistant	Clamp at room temperature	1 yr. dry, 4-12 hrs. mixed	60-80 lbs.	Low	Yes
Expensive, fire hazard, solvent odor, poor creep resistance, special technique necessary	Water resistant	Use contact pressure only	9-12 months	60-95 (double)	Moderate	No
Poor water resistance on wood, toxic catalysts, very expensive	Waterproof	Varies, heat accelerates cure	Indefinite unmixed 5 min. to several hrs.	Varies, usually heavy	High	No
Will not bond to metal, expensive	Waterproof	Hot press 240-260°F.	Approx. 1 yr. unmixed 10-16 hrs. mixed	35-45 lbs.	High	No
Durability and cost in direct proportion to Melamine content	Highly water resistant	Hot press 240-260°F.	6-12 mos. unmixed 3-10 hrs. mixed	30-50 lbs.	Moderate	No
Requires high temp. and pressure, costs more than substitute formulations	Waterproof	Hot press 250-300°F.	Approx. 3 months	20-40 lbs.	Moderate	Yes
Harder to cure, does not have indefinite shelf life, stains under some conditions, will not bond metal	Waterproof	Cure at room or slightly higher temperature	1 yr, unmixed 5 hrs. mixed	50-70 lbs.	Moderate	No
Not good under high stress at low rates of loading, limited water resistance, not good for exterior use	Interior use	Clamp at room temp. 5 min. to 1 hr.	6 months plus	35-50 lbs.	Moderate	No
Discolors (natural glue color) high cost, will not bond metal)	Waterproof	Cure at room or slightly higher temperature	1 yr. unmixed 3-5 hrs. mixed	50-75 lbs.	High	Yes
Very sensitive to fungus even when phenolic modified, structurally weak, requires pentachlorophenol for mold resistance	Interior use	Usually cold press	1 yr. unmixed 3-6 hrs. mixed	50-75 lbs.	Low	Yes
Extremely rigid and brittle glue line, satisfactory only for wood to wood, requires contact of fraying and mating surfaces	Water resistant	Hot or cold press	1 yr. unmixed 4-6 hrs. mixed	35-45 lbs.	Low	No
Extremely rigid and brittle glue line, satisfactory only for wood to wood, requires contact of fraying and mating surfaces	Water resistant	Usually hot press	Approx. 3 months unmixed 1¼-68 hrs. mixed—depending on catalyst	30-40 lbs.	Low	No
About the same limited durability as urea, slightly more expensive	Water resistant	Hot or cold press	3 mos. unmixed 3 hrs. mixed	30-50 lbs.	Moderate	No
Poor water resistance, mold susceptible	Interior use	Cold press	Varies depending on type	35-80 lbs.	Low	Yes
Must be evaluated for production and service conditions, mix proportions must be measured precisely, should be stored below 70°F.	Boiling water resistance after 24 hour room temperature cure; complete cure in 3 min. at 300°F	Clamp at room or slightly higher temperature	24 hrs. at 72°F, 2½ hrs. at 100°F., viscosity will increase but adhesive is satisfactory if it can be stirred. Maximum life at 40° to 60°F.	25-55 lbs.	Moderately-high	Yes some species

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UNIT II

APPLICATION, CLAMPING, AND CURING

Introduction

Regardless of the type of adhesive used, the quality of the glue joint obtained will depend on several other factors, some are related and others are interrelated. In general, these factors may be considered to fall under the following headings: (1) Application (2) Clamping (3) Curing

Application, here, refers to the method of spreading or transferring the adhesive to the surfaces to be joined. Inasmuch as the durability and strength of the bond will be affected by faulty and carelessly applied adhesive, it is very important that one have a thorough knowledge of all the principles pertaining to adhesive application.

Clamping is the process of bringing the members being glued in close enough contact to produce a thin uniform glue line, and to hold them in this position until the adhesive has developed sufficient strength to hold the assembly together.

If the members being joined are machined to a perfect fit, and at the same time a uniform thin glue line is formed, the use of clamps will not be necessary. However, since it is usually impractical to obtain perfectly machined stock, a certain amount of clamping pressure must be applied. Therefore, the many factors concerning clamping must be understood.

Curing is one of the most important stages in the gluing process. Adequate knowledge of the various ways in which an adhesive "sets" or "cures" is vital if one expects to be able to make the proper selection and application of adhesives in the many different types of operations and conditions that are demanded by commercial, industrial, educational, and other practical uses.

In the following sections of this presentation, more detailed information is given concerning the three broad categories of application, clamping and curing of adhesives.

UNIT II

APPLICATION, CLAMPING AND CURING

I. Methods of application of adhesives

A. Methods

1. Brush or roller coating requires little skill and equipment, but labor cost is high and film thickness is not uniform.
2. Plastic squeeze bottle is the most familiar glue applicator in the school shop. The usual sizes are 8 oz., 16 oz., and 32 oz. Some tips are round and some are tapered so as to produce a relatively flat glue bead for ease of spreading with a flat glue spreader.
3. Roller spreading is the most efficient method of applying glue for edge gluing. In most plants the roller spreader is conveyorized. Mechanical roller coating is generally geared to high production, and is not economical for individual parts, sheets or short runs.
4. Spray methods apply adhesives rapidly to odd shapes and short runs, as well as to longer assemblies. The process is much the same as for spray painting. Basic methods are manual and automatic, airless and external mix.
5. Curtain coating uses a variation of the equipment employed for paint, and is the fastest of all the application methods. However, thick sections or parts that are not flat are difficult to coat, and the process is limited to slow-drying adhesives, requiring ovens to remove solvents. Coating uniformity is excellent, material loss is low.
6. Troweling and extruding is usually done by semi-skilled labor and inexpensive equipment.

B. Factors That influence methods

1. Form of Material

a) Liquid, nearly all types of structural adhesives can be obtained in a liquid form.

b) Bulk adhesives come in paste or mastic form.

c) Powdered adhesive is also very common. It may be applied dry or to a primed surface. Powdered adhesives used in the school shop are usually mixed with a catalyst or water.

d) Dry film adhesive may be applied with excellent control of film thickness, and minimum waste.

2. Production Problems

a) The skill of the operator in a gluing operation has a direct bearing on the method of application inasmuch as some adhesives are relatively easy to apply as compared to others.

b) Special equipment is necessary for the application of many types of adhesives.

c) Capitol investment will more or less determine the type of adhesive selected, thereby affecting the method of application.

d) The shape of the bonded surface can also determine the method of application.

C. Tips For Good Gluing

1. All parts of the assembly should be of the proper moisture content, and at the proper temperature. The M.C. should not vary more than 3%, and the temperature should be 70° or warmer in most cases.

2. The gluing surfaces should be free of irregularities, and as even as possible. The joints should be well fitted.

3. The type of adhesive should be the type recommended for the particular job at hand. For exterior use, make sure water-proof glue is employed.

4. Adhesive should be mixed properly and applied according to the manufactures directions.

5. The room should have the proper temperature and some form of ventilation.

6. All joints should be placed under an equal amount of pressure.

7. The pressure should be well distributed and continuous throughout.

8. Allow enough time for glue to set before removing the clamps.

9. Keep all gluing equipment clean and free from hardened glue.

10. Watch for squeeze-out as a check against insufficient glue spread.

11. All clamps should be properly spaced, bar clamps should be placed about 12 inches apart and on alternate sides of stock.

12. Always size coat end of stock to be glued.

I I. Clamping

A. Factors Affecting Clamping Pressure

1. The species of wood has a direct bearing on the amount of pressure necessary to secure a satisfactory glue joint. Softwoods require less pressure than hardwoods and porous woods require less pressure than non-porous woods.

2. Thickness of the layup affects the amount of pressure necessary to bond surfaces together, especially in laminating, where there are multiple glue lines. Therefore, more pressure is required to secure the proper squeeze-out. Thick laminates require 150-200 psi.

3. Various types of adhesives have different chemical compositions and different physical characteristics, which require different amounts of pressure in order to obtain the same amount of wqueexe-out for satisfactory bonding.

4. Good fitting joints require less pressure than poor fitting joints. Higher pressure, however, does not compensate for well machined joints.

5. High-viscosity adhesives generally require greater pressure to secure a thin film than low viscosity adhesives.

B. Factors Affecting Clamping Pressure Time

1. Temperature and humidity are important. Better results will be obtained with most adhesives if the temperature is 70°F or warmer, however, there are some adhesives that work well in temperatures lower than 70°F.

2. Certain woods require longer clamp time than others. Ring porous woods require longer clamp time than diffuse porous woods.

3. The adhesive affects the speed of set in many ways. An adhesive with a high per cent of solids will often set faster than one with a lower per cent of solids. An emulsion adhesive releases its water more easily than an adhesive dissolved in water

4. Moisture content has a bearing on the clamping pressure time. The speed of set is directly related to the drying of the glue in the joint. It can readily be seen that drier wood with its faster water absorbency, will set faster than higher moisture content wood. Therefore, the greater the moisture content, the longer the clamps should remain on the stock.

5. The type of work being done has a decided effect on the clamping pressure time. Edge gluing may require more time to set than panel-to-frame gluing because of the differences in dimensions of stock involved. Heavy laminates may require more time to set than assembly gluing because of the direction of the grain in the two types of gluing. Often, in assembly gluing, the end grain is joined to side or edge grain. In laminating, the members are usually joined face-to-face. This produces thicker stock, thus increasing the time required for the glue to set and the clamping pressure time.

C. Assembly Time

1. Closed assembly time is the time between the closing of the assembly and the application of pressure.

2. Open assembly time is the time between application of the adhesive and closing the assembly.

D. Clamping Time and Prêssure of Various Adhesives at 70°F

Glue	Hardwood	Softwood	Pressure
Animal Hide	2 hrs.	3 hrs.	50-75 psi.
Polyvinyl	1 hr.	1 1/2 hrs.	25-100 psi.
Resorcinol	8-10 hrs.	8-10 hrs.	25-75 psi.
Plastic Resin	16 hrs.	16 hrs.	50-75 psi.
Casein	2 hrs.	3 hrs.	50-75 psi.
Contact Cement	none	none	Momentary
Epoxy	3 hrs.	3 hrs.	10 psi. max.

E. Pressure Obtained From Various Clamps

1. Bar Clamps.

a) One hand applied easy--200 - 400 lbs.

b) One hand applied hard--400 - 800 lbs.

c) Two hands applied easy--800 - 1200 lbs.

d) Two hands applied hard--1200 - 1600 lbs.

2. Handscrew and C-Clamps

a) Adequate pressure is applied over a wide area.

b) Because of the spindle handle it is very difficult to apply too much pressure.

III. Curing of Adhesives, Eight Methods

A. Absorption of the vehicle (generally the water in the adhesive) into the stock being glued or joined, is the most common method of setting when at least one of the surfaces to be joined is porous-paper, fiberboard, wood, or other fiber material.

B. Evaporation of solvent or vehicle method of drying, requires access of air to the wet adhesive film so the solvent can evaporate (either directly into the air or through the porous material being joined).

C. Oxidation of film is the way oil paints set to a hard film. Again, it is necessary that air have access to the wet adhesive.

D. Chemical setting by the reaction of the constituents in the adhesive to form new substances, which are strong adhesives is another method of curing. A catalyst (either added to the adhesive before use, or to the film after it is spread) can be used to trigger such setting. Many of the modern resin adhesives for metal to metal bonds, are set by the use of heat. (Heat can act as a catalyst.)

E. Cooling and evaporative curing occurs in adhesives which have been rendered fluid by prior heating. Animal glue is the most common example of this type.

F. Heat setting or curing is required in "thermosetting" resins. Thermosetting resins are applied in a fusible state and upon the application of heat they "polymerize" or "cure" and are transformed into an insoluble, infusible solid of great strength and stability.

G. Congealing due to temperature decrease in an adhesive, rendered fluid by prior heating, occurs in many so called "thermoplastic" or "hot melt" adhesives. These products are in a solid or semi-solid state at room temperature and are applied while in the hot liquid state. Upon cooling, these materials solidify and rapidly pick up strength.

H. Self sealing or cohesion is the eighth method of curing adhesive. Such a dry adhesive film has strong affinity for another of the same composition, but no affinity for other surfaces. In such bonding, both surfaces to be joined must be treated. When the dried films are brought into contact, they bond or cohere immediately. These products are frequently confused with pressure sensitive adhesives which are applied to one surface only.

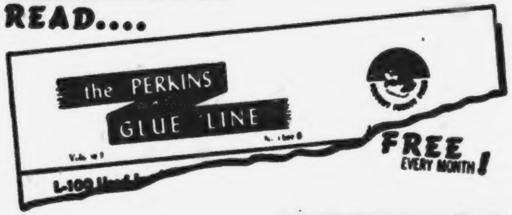
AN INTRODUCTION TO *High Frequency Gluing*

By LAURENCE E. CLARK, JR.

A number of articles on this subject have appeared in trade publications. Some have covered the problem from the highly technical standpoint and others from the purely practical.

This article is primarily intended for the person who does not use high frequency heating, but has heard about it and wonders whether he is "missing something" by not knowing more about it.

READ....



The purpose of the "Glue Line" in discussing the subject is not to advocate — nor condemn — the use of radio frequency heating. We only submit some of the evidence we have obtained on the subject, for the information of our readers.

Fundamentally, there is nothing mysterious about radio frequency heating. The heat is the same sort of energy produced by steam, gas or an electric toaster. It is measured in the same units of heat (calories or British Thermal Units) and the same temperature scale is used for recording the temperature rise.

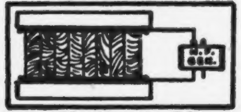
The principal difference between radio frequency heating and other methods of producing heat is the manner in which the heat is generated. Conventional heating methods apply the heat to the surface, and a period of time is required for the heat to "soak in" to the center of the assembly. With radio frequency heating (hereafter called R.F. heating) the whole mass of wood or other poor electrical conductor is raised uniformly at a rate depending upon the electrical characteristics of the material in question. The "soaking period" is eliminated.

The fact that radio waves are able to penetrate the assembly without a soaking period is not unexpected, as you usually do not have trouble operating a household radio inside a frame building. In the same manner that radio waves can easily penetrate the walls of a house, they penetrate with similar ease the material to be heated in R.F. heating.

The radio waves used in R.F. heating are the type found in the "short wave" band of the household radio. They run in frequency from 2 to 30 megacycles, just above the "broadcast band" which runs roughly from one-half to 1.6 megacycles.

A transmitter, or generator, is required to produce the radio waves and instead of broadcasting them by means of an antenna, the waves are confined between metal plates. The assembly to be heated is placed between the plates (called electrodes). Frequently the R.F. heating generator has greater power than most commercial broadcasting stations.

PARALLEL BONDING

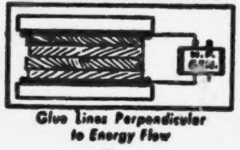


Glue Lines Parallel to Energy Flow

(FIG. 1)

A certain amount of broadcasting or radiation does take place and for this reason the Federal Communications Commission requires the user of R.F. heating to isolate his generator and work area by enclosing it in a metal shield or enclosure to absorb the energy and reduce radio interference. In planning the cost of a radio frequency installation, it is necessary to include the cost of adequate shielding. This information can be supplied by the manufacturer of radio frequency generators.

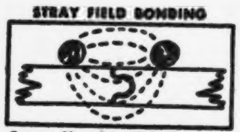
PERPENDICULAR BONDING



Glue Lines Perpendicular to Energy Flow

-2-

STRAY FIELD BONDING



Energy Flow Fans Out, Converging on Opposite Electrode

-3-

Radio frequency energy can be applied to the work by one of three systems:

The first type is known as perpendicular heating and is employed to heat the whole mass of work placed between the electrodes, the glue lines being parallel to the electrodes. This system is used in laminating, and for making flat and curved plywood. (See Fig. 2.)

The second system is known as parallel heating. Here the glue lines are at right angles to the electrodes, generally in contact with one or both of the electrodes. (See Fig. 1.)

The third method is known as stray field heating, and in this case the both electrodes are on the same side of the glue line. In cases where it is not possible to place the work between the electrodes in either of the previous heating methods, stray field heating is used. (See Fig. 3.)

A true picture of the merits of R. F. heating can only be understood after analyzing the three methods of energy application. In the case of perpendicular heating, it must be remembered that all the material between the electrodes must be heated, and there will be a certain amount of heat lost to the plates of the press, or metal covered forms, in the case of curing curved plywood. The plates, or electrodes must be made of metal and they conduct heat away from the surfaces which they contact.

To roughly calculate the amount of heat necessary to cure a load with R. F. heating by the perpendicular method, multiply the weight of wood and glue to be used in a given load by 0.45 (the specific heat of wood) times the number of degrees Fahrenheit the load must be raised to reach 180 to 200 degrees final temperature. This is the temperature at which most cold setting urea formaldehyde resins will cure. The result of this calculation gives the number of British Thermal Units required to heat the load.

Radio frequency generators are sometimes rated by British Thermal Units, but generally they are rated by their electrical output in watts. To obtain the number of watts per minute to raise the temperature, divide the result of the above calculation by 56 which is approximately the number of BTU in one kilowatt minute.

Example: If the wood weighs fifty pounds, and the room temperature is 80° F., multiply $50 \times 0.45 \times 100 = 2250$ BTU. $\frac{2250}{56} = 40.17$ kilowatt minutes. A ten kilowatt generator will divide the figure by ten showing that approximately four minutes will be required to heat the load. This does not take into consideration the heat losses to the form, and assumes 100% of the power from the generator is reaching the material between the electrodes. In most installations, the loss can be assumed to be about ten per cent, which would mean it would take about four and one half minutes to properly cure the load. The complete cure would not take place at that time, so

A REPRINT FROM "THE PERKINS GLUE LINE"

the material as it comes from the press should be stacked solid and the heat stored in the bundle will quickly bring the glue lines to a completed cure.

The stored heat principle can be used quite effectively in this method of heating, and if the stock is flat, even greater reductions in the curing cycle can be made. If the work is curved plywood, or heavy laminations which place considerable strain on the glue line, it is desirable to bring the cure to a fairly complete state before removing pressure, so that no deformation will take place.

This method offers considerable merit in the manufacture of curved plywood such as seat backs or curved fronts commonly found in modern furniture design. The cost for jigs and fixtures is nominal when we consider the forms are made from wood covered with thin sheets of copper or aluminum, to act as electrodes. Steam heated forms of similar design would be very expensive and limited in use to the single design. The initial outlay for an R. F. generator is of course a considerable investment, but it can be used with a wide variety of shapes and sizes of forms.

Parallel heating is the most widely adopted form of R. F. heating in use today. It has found ready acceptance in the manufacture of core stock where it heats and cures resin glue lines in a matter of seconds. The use of this type of energy application is limited to material such as core stock, because the heating is uneven if the distance between electrodes exceeds three inches. For this reason it has not been adapted to laminating of structural timbers and similar work.

Two types of electrode construction are used in parallel heating. In one case a single metal sheet is used as a hot electrode, and another for ground. All the glue lines running between these plates will be rapidly heated. The speed with which this takes place will of course depend upon the rating of the R. F. generator.

When large glue line areas are to be heated with a relatively small generator, another method of electrode design is employed. Instead of solid metal sheets, strips of metal are employed, with all the strips on the same side of the glue line connected together. Of course, only that part of the glue line falling between the hot electrode and ground strip will become heated, and in a sense the core stock is "tacked" holding the pieces in place until the balance of the glue line cures at room temperature. The space between metal strips will depend upon the strain to be placed on the glue lines after the pressure has been removed.

Great progress has been made in designing parallel bonding equipment. Some machines handle the stock automatically by a batch process, and others handle the stock continuously. Both methods work very effectively under most conditions, and the choice lies in how much the buyer can invest in this type of equipment.

Stray field heating is the least effective method of using R. F. heat, but its special applications are numerous. Because it is not always possible to place electrodes on opposite sides of work to be glued, both the lead from the generator (hot electrode) and the lead to ground may be placed on the same side of the work. Some of the energy will travel along the surface of the work, but some of it will penetrate to the underlying glue line and heat it, quite effectively. This method is employed in blocking, banding, and for bonding plywood to frames in panels for pre-fabricated houses. The distance from the electrodes to the glue line in this type of heating must be less than half the distance between the "hot" and ground electrode. The set-up is not limited to a single pair of electrodes, of course. It is possible to design a group of electrodes, with all the "hot" type connected together, alternated with those connected to ground.

Portable R. F. gluing equipment employing the stray field method of energy application is available for blocking and heating of small areas, sometimes referred to as "tacking" operations.

Special attention should be given to the adhesives used with this type of heating. When R. F. heating was first introduced, the perpendicular heating method was employed. The adhesives for the most part were the conventional cold setting urea and resorcinol glues. Any adhesive that was cured rapidly by the application of heat worked well, as far as curing was concerned. It was noticed, however, that when the glue squeezed out of the glue line and ran down the side of the construction, it was sufficiently conductive to absorb large quantities of the R. F. energy and cause arcing and burning. For this reason, special glues were developed that had a low-arcing tendency.

Ureas Satisfactory

At present it can be said that most cold setting urea resin formulations can be used with satisfaction in perpendicular heating. Some resorcinol resins are less than others. All high temperature phenolic resins behave poorly unless great care is given to the quantity of glue spread, to minimize squeeze-out. Acid cured phenolics are being used with fair success although their curing rate is slower than for urea resins.

Parallel heating, which depends upon the fact that the glue is more conductive to R. F. energy than the wood, requires special consideration. Best results can be obtained with glue formulations specifically designed for R. F. work.

One method of making a glue more conductive is to add table salt to a cold setting resin mixture. This does cause the glue line to heat rapidly, but it often is accompanied by burning and arcing. Special formulae, designed by the glue manufacturer for R. F. work have eliminated the burning problem, and at the same time have increased the setting speed.

Fifteen Seconds Minimum

Best glue joints cannot be obtained if the glue line is cured in less than fifteen seconds, regardless of the size of the generator being employed. A urea resin cures by chemical reaction in the presence of water. Too rapid a heating of the glue line can cause boiling of the glue line which makes it weak and granular — or the glue line can theoretically dry out faster than it can cure, leaving a partially cured resin, which never will cure, because the required moisture has been driven out.

Adhesives for stray field heating should be of the same type used in parallel bonding as they depend upon the fact that the glue is more conductive than the wood, to cure rapidly.

In summarizing our observations regarding R. F. heating we have observed that for production applications of R. F. heating — the volume of work should be the determining factor. If a large volume of core stock or edge gluing of solid stock is required, R. F. heating can usually offer substantial savings in time and labor.

Inexpensive Dies

Complicated curved pieces can be turned out in large volume with perpendicular heating methods using inexpensive dies and molds. The size of the generator should be given careful consideration in this case as an undersized unit may not be able to show a substantial savings over cold press methods, particularly if the prospective user of R. F. equipment has the forms and clamps on hand for cold pressing.

It is generally not economical to manufacture flat plywood by R. F. heating as hot presses can give a less expensive source of heat. However, if the R. F. generator is being used on some other work in the plant it can frequently be adapted to hot pressing of small orders of plywood — when cold pressing is the general method employed by the manufacturer.

Many people are afraid of R. F. heating because they have heard of the high voltages employed, and are worried about their employees getting injured by coming in contact with the equipment. A well designed R. F. installation manufactured by a reputable R. F. Company will have safety features incorporated which will make it impossible to come in accidental contact with the high voltage transmission equipment. Of course it is not possible to make the equipment absolutely "fool proof," but it has been made as nearly so as human ingenuity can devise.

PERKINS GLUE COMPANY
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Precaution Will Eliminate Failures In R. F. Gluing of High Density Woods

By L. E. Clark, Jr.

When Radio Frequency edge gluing machines are used on core stock, there is usually no difficulty with medium and low density wood species such as gum and poplar.

When these machines are used for edge gluing solid lumber tops of high density species, such as birch, beech and maple, some users experience difficulty with open joints and, frequently, complete glue line failure.

This has led some to believe a deterioration of the glue line has taken place and great skepticism has arisen about the desirability of using R. F. for gluing solid stock.

Insufficient Glue

Actually, in the instances of failure that have come to our attention, the trouble has been caused by "starved" glue lines. No deterioration of the glue line has taken place, but rather there was not enough glue present in the joint to form a strong bond.

Sometimes the glued stock has gone through machining, without any gross indication of failure, yet a week or more later the joints open up. This is due to the vagaries of wood. The stresses locked in the glue joint finally cause a failure. This may be due to changes in relative humidity or temperature, or by the exposure of new surfaces brought about by end trimming and/or surfacing.

If the glue joint is good and without strains in the first place, the joint will not fail. Checks in the wood may result, but resin glue joints, well prepared, have been repeatedly proven to be stronger than the wood itself.

Greater care must be taken in the selection of stock, when high density species are used. The bending strength and other physical characteristics of a piece of maple or birch are great and if high edge or top pressures are required to flatten or straighten a board, the defect is not permanently removed. To be sure, the board now appears desirable, but the stresses are still there, waiting for a chance to release themselves. This may fortunately happen in the early stages of fabrication, but joints can easily hold until the finished product is in the hands of the dealer or ultimate consumer.

It is much safer economy to use stock requiring a minimum of pressure to bring it into position. Adverse moisture and temperature conditions can work enough havoc, without giving the wood a further reason for undesirable behavior.

When using radio frequency heating for preparing glue joints in high density species, the uniformity of the glue line thickness is an important consideration. Electricity has the characteristic of following the path of least resistance and thinly spread glue areas offer high resistance. Warped and twisted boards when brought forcibly together will have thin glue lines at the point of initial contact. The thicker sections will therefore draw most of the electrical energy and cure rapidly.

May Arc

Often the thick cross sections will draw more energy than they can safely stand and an arc may result. The thin-spread areas may develop burns due to localized increase in voltage resulting from the radio frequency energy trying to force itself across a non-receptive path.

It is true that perfect boards are not always available for practical production use and the "pipe dreams of the theorizer" are not acceptable to the trade. In such cases, a compromise must be reached. Reject all the badly twisted boards and rip all but the good ones into narrow widths so the strains will be reduced to a minimum.

Perkins has cooperated in some investigations along this line with a manufacturer of radio frequency equipment, with interesting conclusions.

Two methods of increasing the speed of set of a resin glue line when used for radio frequency may be employed. The addition of electrolytes which will increase the conductivity; or the increasing of the cross section of the glue line. In the same manner that copper is a better conductor of electricity than some other metals, it is possible by increasing the cross section of the inferior conductor to have the same conductivity as a smaller copper wire.

Ordinarily it is not possible nor desirable to have thick cross sections of glue line. However in the method used the thick cross section is temporary. Due to the use of an automatic time delay in application of side pressure, the R. F. energy is allowed to flow for a few moments before the cross section is reduced. This allows the glue to pass through the very thin stage, when most starved joints are caused under high edge pressure.

Other Methods Satisfactory

Satisfactory bonds of high density species may be obtained on most all radio frequency presses, without the use of the apparatus mentioned in the preceding paragraph and we are mentioning this method to keep our readers posted on the work being carried out in this field.

There are several Perkins formulations for obtaining satisfactory bonds in the edge gluing of high density stock. Further information on them may be obtained directly from the Company or from any Perkins' representative.

Use pressure adequate to bring the joints into intimate contact, but the presence of excess quantities of glue on the surface of the cured panel is an indication that the spread is too heavy or the side pressure too high.

A medium spread of uniform thickness is desirable with a delayed assembly period whenever possible, to allow the glue to thicken before pressure and heat are applied.

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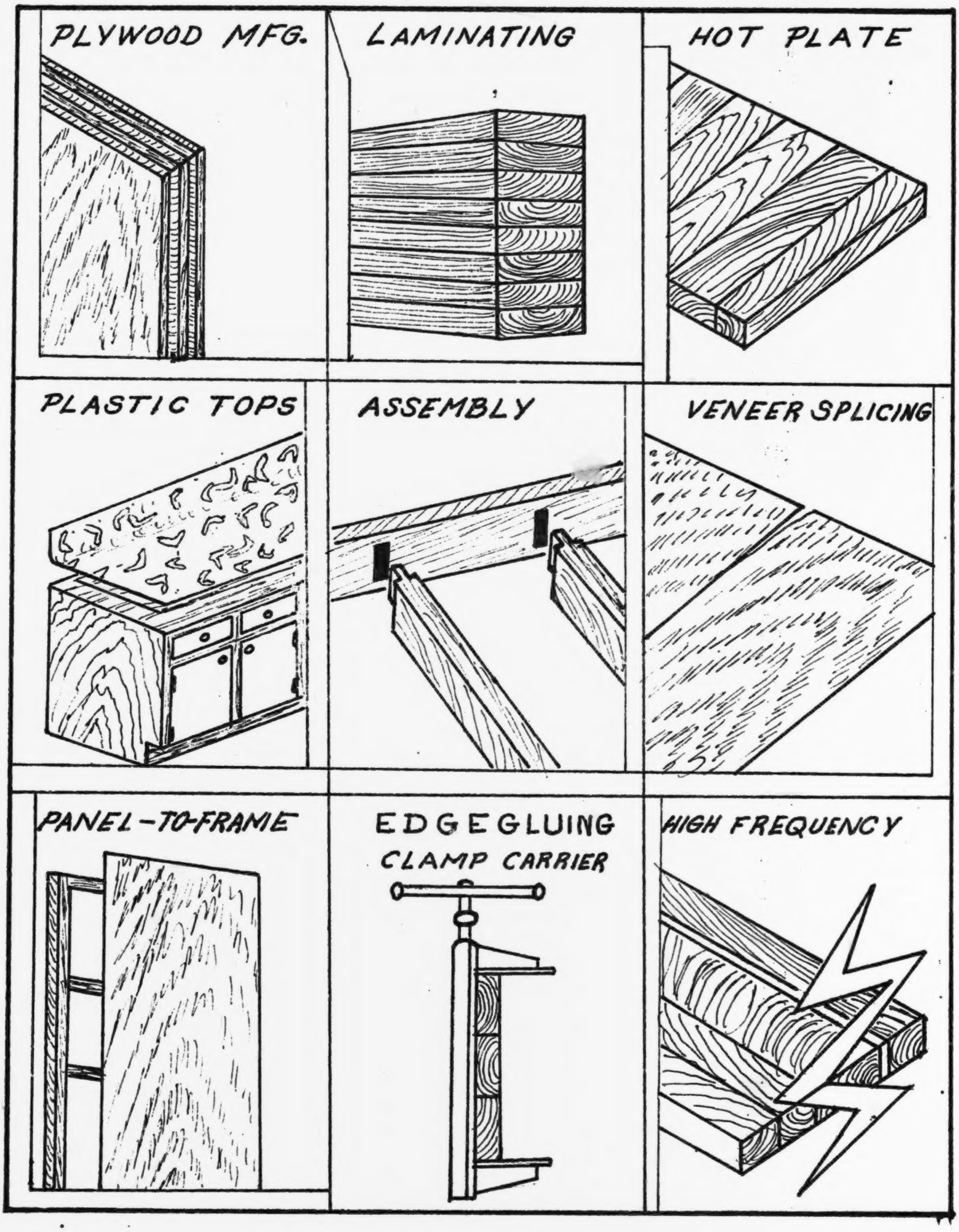
NINE TYPES OF GLUING OPERATIONS


PLYWOOD MFG.
LAMINATING
HOT PLATE
PLASTIC TOPS
ASSEMBLY
VENEER SPLICING
PANEL-TO-FRAME
EDGEGLUING
CLAMP CARRIER
HIGH FREQUENCY

Borden's TROUBLE-SHOOTER

FOR HOT-PRESSED PLYWOOD OR FURNITURE PANELS

(many of the Faults, Causes and Rules for Good Gluing apply also to cold-pressed panels)

RULES FOR GOOD GLUING

Storage

1 Rotate your stocks, avoid over-aged glue, and store glue in a cool, dry place.

Ingredients in the Glue Mix

2 Choose the correct type of glue and catalyst for your plant conditions.

3 Determine mixing proportions of ingredients (particularly powders) by weight and not by volume.

4 Use just enough water to provide proper spreading consistency.

5 Use only fresh, white wheat flour extender with low ash content and low water-taking capacity, and do not impair the water-resistance of the bond by using too much extender. See Service Bulletin No. 81.

6 Use shell flour (Glufil) as 10 to 25% of total extender—to prevent bleed-through and excessive penetration.

Mixing

7 Keep your mixer clean and in good working order, and remove all traces of cleaning compounds before using mixer.

Add the ingredients in the order directed, for best results. When mixing powders, make a heavy mix first—then add water.

Use water between 60 and 70° F.

Do not fill mixer to more than 2" above top blade.

8 Operate mixer at 60 to 65 rpm.

9 Do not let mix stand for long periods before it is used.

Kiln Drying, Veneer Drying, Plant Conditions

10 Do not dry core stock or veneers below 5% unless they will pick up moisture before use.

Humidify glue room if heating system dries air below 25% relative humidity. See Service Bulletin No. 69.

11 In wet seasons, dehumidify plant or keep stock dry in special storage.

12 Maintain plant temperatures at 70° F. or higher where urea resin glues are cured at room temperature.

13 Allow kiln dried veneers and core stock to cool before spreading.

Core-stock

14 Avoid core stock with worm-holes, dents, knots, etc. And do not use dopes and fillers that absorb and hold an excess amount of water.

15 To prevent warping: Do not use woods of different density in the same cores. Do not use wide boards in core stock. Avoid rough, rotary cut veneer cores.

16 To avoid sunken joints in core stock, do not surface cores too soon after edge gluing.

17 Keep planers in adjustment to avoid planer marks and dips in core stock.

18 Do not surface cores unless they will be used within a few days.

Veneers

19 Avoid wavy and warped veneers where possible.

20 Do not use veneers of unequal thickness in the same crossband or as core stock.

21 To prevent warping: Avoid diagonal grain veneers. Use same species and thickness of veneers, where possible, for faces and backs. See Service Bulletin No. 75.

22 Avoid thick tapes or marquetry on face veneers.

23 Use minimum spread when splicing to avoid squeeze-out at the splicer joints.

24 Be sure veneers are within the proper Moisture Content range for the adhesive being used.

Spreaders and Spreading

25 Recover and regroove worn spreader rolls.

Replace worn bearings on spreader rolls.

Use proper grooving for the type of glue and spread required. See Service Bulletin No. 85.

Be sure glue rolls are aligned with each other and with doctor rolls.

Keep spreader rolls clean of dried glue.

Be sure top and bottom rolls apply equal spread.

26 Apply the proper spread for the adhesive mix being used and the condition of the stock. Rough, loose-cut and porous stock requires a heavier spread than smooth, dense stock. See Service Bulletin No. 85.

Handling Spread Veneers

27 Do not wipe glue off crossband by sliding lumber core on spread veneer. Also avoid wiping glue off gluing area with gloves.

Assembly

28 When spread veneers are warped and loosely piled, consider it as "open assembly."

29 Use a longer assembly period to prevent blisters (hot press), bleed-through or starved joints (on dense stock). When long assembly is required, use, if necessary, a slower catalyst and longer pressure period.

30 Use a shorter assembly period or slower catalyst to prevent precuring. (Where short assembly time is practiced, a fast catalyst may be used to obtain faster cure.)

31 Be sure that all panels in one press opening are the same thickness.

Caul boards

32 To avoid precure, cool hot-press cauls before assembly.

33 Keep cauls clean, smooth and waxed.

Presses and Pressure

34 Be sure all steam traps are working properly, and clean out channels in the platens if they appear to be water-logged.

35 Be sure steam pressure is adequate to attain required press temperature, and do not start pressing until press is fully heated.

36 Use automatic loader where necessary, and be sure press closes quickly.

37 Be sure press is not out of line causing uneven pressure.

38 Be sure press delivers recommended pressure so that all surfaces are brought into intimate contact.

39 Avoid excessive pressures on dense stock unless delayed assembly is used.

Pressure Periods

40 Do not use high hot-press temperatures to attain short pressure periods unless moisture content of stock is carefully controlled.

41 To avoid excessive drying or over-curing, do not leave panels in the hot press during lunch hours or "break" periods, and always remove panels as soon as the press is opened.

Conditioning of panels

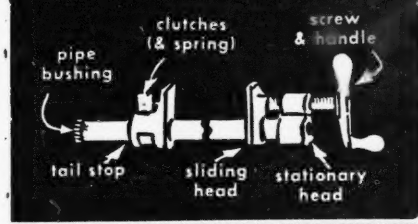
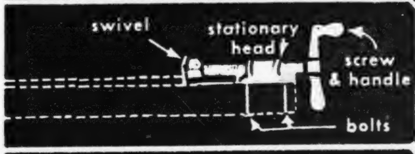
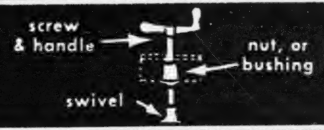
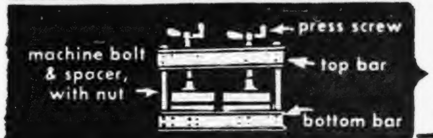
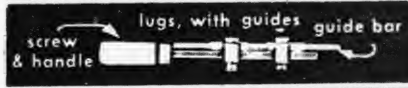
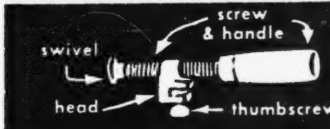
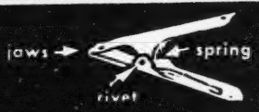
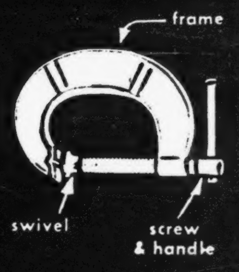
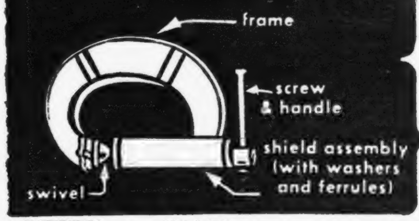
42 For quickest cooling or heating of glued panels, they should be stickered.

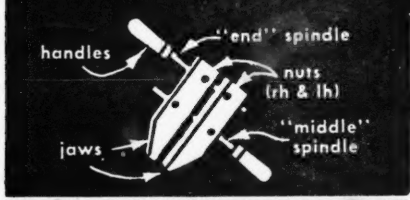
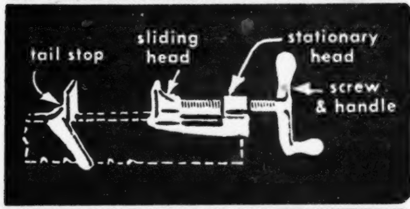
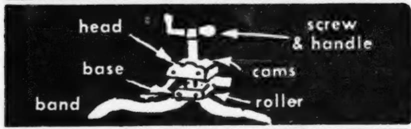
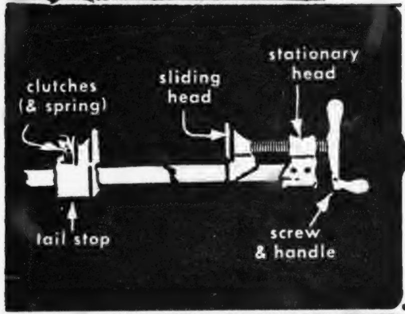
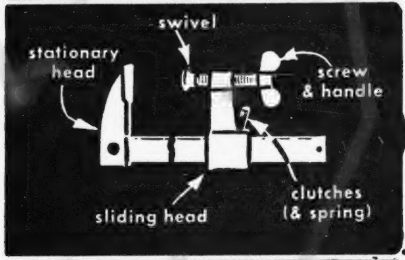
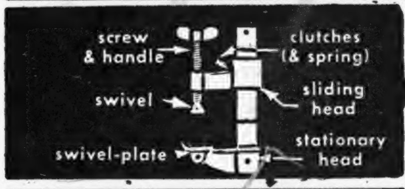
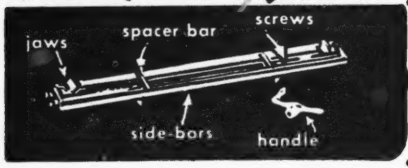
43 For gradual cooling of panels, to prevent warping, they should be squarely dead piled and weighted for at least 12 hours. See Service Bulletin No. 75.

44 Allow a maturing period during which complete cure develops, before testing.

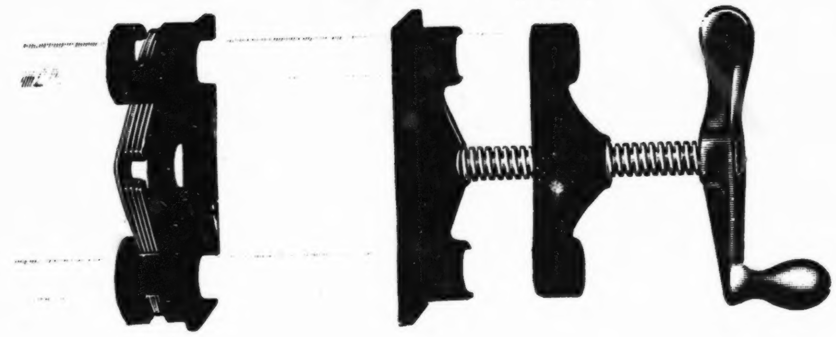
Gluing Fault	Possible Causes	Apply these "Rules for Good Gluing"
Blows or Blisters (Mostly in center part of large panels, in all-veneer construction and between core and crossband)	Press time too short	2, 40, 29
	Moisture content of stock too high	11, 24
	Non-uniform Moisture Content (wet spots)	14
	Assembly time too short	29
	Spread too heavy (all over or in spots)	17, 25
	Press temperature too high	40
	Presence of defects in the stock	14, 17
	Adhesive mix too thin	4
Precure (No transfer or spotty transfer of glue from crossband to face or back or to cores. Spreader marks show on crossband)	Adhesive mix too reactive	2, 3
	Spread too light or non-uniform	26, 27, 25
	Assembly time too long	30, 36
	Hot veneers or cores	13
	Hot cauls	32
	Press temperature too high	40
	Porous veneers	26
	Use of stock of non-uniform thickness	18, 20, 31
Bleed-through (Areas difficult to finish, won't take stain, etc., due to excess penetration of glue)	Faulty type of extension	6
	Face veneers too high in Moisture Content	11
	Adhesive mix too thin	4
	Spread too heavy	26
	Assembly period too short	29
Warpage (Any variation from flat, true panel)	Unbalanced construction	21
	Non-uniform moisture content	10, 11
	Non-uniform spread	19, 20, 25
	Faulty core stock	14, 15, 16
	Press temperature too high	40
	Over-curing in the Hot Press	41
	Improper conditioning	42 or 43
Starved joints (Weak bond. Glue transfers, but very little glue in joint.)	Foamy mix	4, 8
	Adhesive mix too thin	4
	Spread too light	19, 26
	Assembly time too short	29
	Excessive pressure	39
	Porous stock	26
	Faulty type of extension	5, 6
Spotty Bond (Good in some areas. Poor in others.)	Insufficient or non-uniform pressure	18, 20, 22, 31, 37, 38
	Non-uniform spread of adhesive	14, 16, 17, 19, 20, 25
	Uneven press temperature	34
	Assembly time too long for certain areas	28, 30, 36
	Face veneers too well sized	23
	Improper mixing	7, 8, 9
	Careless veneer handling	27
Weak Bond (powdery glue-line—see also "Precure")	Stock (particularly cores) too dry	10
(Green or moist glue line)	Adhesive mix not reactive enough	1, 2, 3
	Press temperature too low	34, 35, 12
	Press period too short	30, 40, 12
	Moisture content of stock too high	11, 24
	Spread of adhesive too heavy	26
Face Checking	Moisture content of stock too high or too low	10, 11, 24
	Improper conditioning	42 or 43
	Press temperature too high	40
	Press period too long	41
Indentations	Defective equipment	33
Low water-resistance (With good dry strength)	Testing before 4 to 6 days' maturing	44
	Too high or faulty type of extension	5

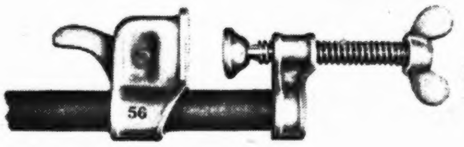
CLAMPS

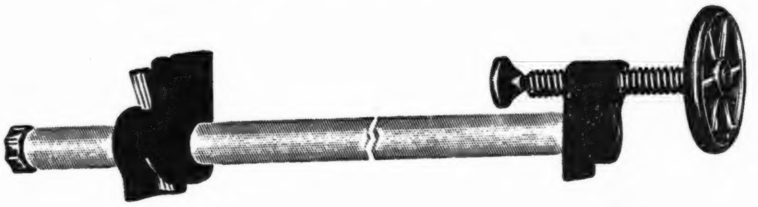
	GENERAL DESCRIPTION	SPECIFIC TYPE	SPECIAL FEATURES
 clutches (& spring) screw & handle pipe bushing tail stop sliding head stationary head	**CLAMP FIXTURES** for use on pipe. Mount on ordinary black pipe, any length, to make economical, instant-acting bar clamps. No tools required to assemble — just the pipe threads. One of the handiest tools in any shop.	Uses ¾" pipe. The most popular all-purpose style. Uses ½" pipe. A light weight design, low reach. "Double-bar" type, uses ½" pipe. Bars straddle the work to eliminate "buckling". "Sliding head" type. CAN BE REVERSED to push work "out" instead of pulling it together.	Instant-acting "MULTIPLE DISC CLUTCH" permits *zip* adjustment to the work — holds securely — releases easily. Clutches encircle pipe, hold top and bottom—will not crush the pipe or fill up with "filings". Clutches are reversible. Easy to mount on different lengths of pipe to fit the job.
 swivel stationary head screw & handle bolts	**JIG and FIXTURE ASSEMBLIES** To make special jigs and fixtures for all types of fabricating and assembly.	May be mounted on any flat surface —any position. Provide positive screw action. (Also see "Press Screws" and "Edge Clamps" and "Hinged Clamps".)	Length of bolts is only difference between the two numbers.
 screw & handle nut, or bushing swivel	**PRESS SCREWS** For making up veneer press frames, jigs and fixtures, for wood and metal assembly jobs.	11/16" dia. screws, for "industrial" service. ½" dia. screws, for light service.	May be mounted to press "down", "up" or "sideways". Special literature available.
 press screw machine bolt & spacer, with nut top bar bottom bar	**VENEER PRESS FRAMES** Ready-made frames for single and "small run" veneering and assembly.	Available in 18" and 36" widths. Hard-maple cross members strengthened by steel channels.	Easy to use and store. Frames "in series" take work of any length.
 lugs, with guides guide bar screw & handle	**MITRE CLAMPS** For mitering heavy, flat casings.	Lugs pull any-degree mitre, with no creeping or pulling away.	Used where back of work can be bored with ⅝" dia. blind holes.
 screw & handle swivel head thumbscrew	**EDGE CLAMPS ("Cross" Clamps)** For applying pressure to any work "edge"—and to center area of wide surfaces.	Attach to any steel bar clamp having bar no more than 5/16" thick. Applies pressure at right angles.	Very handy attachments for clamping moulding and trim on edges. Also for applying pressure to center areas. No. 642 straddles clamp bar, equalizing pressure over broader area.
 jaws spring rivet	**SPRING CLAMPS** Convenient, spring-operated jaws hold any material quickly, efficiently.	Hand pressure opens the jaws—spring pressure clamps the work. Very rapid action.	Tempered springs are strong—use where secure screw-pressure is not required.
	"C" CLAMPS—The most widely used type of clamp.		
	A. VERY LIGHT SERVICE	Capacities to 3". Made for "industrial" service.	Rust-proof finish, closely fitted screws. Choice of handle-types.
 frame swivel screw & handle	**B. "REGULAR" SERVICE** For all ordinary "C" clamp requirements, where extreme strength is not required.	Most economical all-purpose design. Capacities 2½" to 12". "Quick-acting" type. Capacities 2½" to 8". "Deep Throat" design, for reaching around and over.	Correctly, liberally proportioned frames. Cold-drawn steel screws. Screw slides to adjust. *See "sliding head" bar clamps before ordering.* Correctly, liberally proportioned frames. Cold-drawn steel screws.
	C. "INDUSTRIAL" SERVICE	Heavier, stronger design, deep throat. Very reasonably priced. Drop-forged steel frames, strongest for the weight. Heavy-duty type, for machine, boiler, welding and similar shop work.	The greatest *value* in "C" clamps—note "load limits"—and prices! Will take shock and vibration loads well. Heavy, ribbed heat-treated frames, 13/16" dia. screws.
 frame screw & handle shield assembly (with washers and ferrules) swivel	**D. "WELDING" SERVICE** Exclusive, patented "JORGENSEN" Shield over the screw provides *positive* protection.	For "regular" service. Deep-throat —very strong for the weight. Heavy duty design, 2½" depth of throat. Heavy duty design, *deep throat.*	Heavy steel SHIELD over full length of clamp screw affords POSITIVE protection from "spatter" and other damage. Built for the extreme service demanded of welders' tools.

	GENERAL DESCRIPTION	SPECIFIC TYPE	SPECIAL FEATURES
 handles "end" spindle nuts (rh & lh) "middle" spindle jaws	**HANDSCREWS** Most satisfactory holding device for wood, metal, plastics, fabrics—all materials. Will hold irregular shapes.	"Adjustable" type—jaws adjust to angles to hold uneven work. The most popular design. "Non-adjustable" type—jaws always remain practically parallel	The hard-maple jaws hold more securely than metal clamps. Will not crawl or twist. Broad area of pressure reduces tendency to mar work. Jaws provide greater "reach" over the work.
 tail stop sliding head stationary head screw & handle	**WOOD BAR CLAMPS and FIXTURES** For those who prefer the qualities of wood in the bar, sacrificing some of the strength and rapid action of steel bar clamps.	For fine cabinet work. Light in weight, with minimum of exposed metal parts. "Fixtures only"—to be mounted on wood bars 1¼" x 2½". "Fixtures only"—to be mounted on 2 x 4's.	Leather padded jaws are less likely to mar finished surfaces. Preferred for "economy". However, "PONY" Clamp Fixtures, used on ordinary black pipe, are much more popular. See Styles #50, #52, #53, #56.
 head screw & handle base cams band roller	**BAND CLAMPS** For clamping irregularly shaped forms and assemblies.	Canvas or steel band encircles the work, is drawn tight by screw action.	Use steel band on round shapes only. Canvas band always furnished unless steel is specified. Steel band is not interchangeable onto a clamp designed for canvas band, and vice versa.
	BAR CLAMPS—(steel)	**Available in a wide variety of styles and sizes. For clamping over long "spans"—or, in the shorter lengths, used in place of "C" clamps for instant-adjustment.**	
 clutches (& spring) sliding head stationary head tail stop screw & handle	**A. "FIXED HEAD"** (Screw is in the "stationary" head.) The most widely used general-purpose type of steel bar clamp.	I-Section bar offers visible assurance of strength. Flat spring-steel bar provides greatest strength for the weight.	Instant-acting "MULTIPLE DISC CLUTCH" permits *zip* adjustment to the work — holds securely — releases easily. No notches in the bar to weaken it.
		Flat, notched spring-steel bar. Flat, notched spring-steel bar—crank handle.	Notches in the bar hold the tail-stop under clamping load. Not as strong or fast as Nos. 70 and 40.
		Light, fast-operating design for edge-gluing and other light work. Light, fast-operating design for general purpose use.	Instant-acting "MULTIPLE DISC CLUTCH" permits *zip* adjustment to the work — holds securely — releases easily. No notches in the bar to weaken it.
 swivel stationary head screw & handle sliding head clutches (& spring)	**B. "SLIDING HEAD"** (Screw is in the "sliding" head.) All adjustment is on the sliding head—very convenient in close quarters. Widely used in place of "C" clamps because of instant-adjustment to the work.	Popular light-weight, deep-reach design. Light-weight—less reach but stronger than No 39. Heavier design with "medium" reach. Heavier design with "deep" reach.	Instant-acting "MULTIPLE DISC CLUTCH" permits *zip* adjustment to the work — holds securely — releases easily. No notches in the bar to weaken it.
 screw & handle clutches (& spring) swivel sliding head swivel-plate stationary head	**HINGED CLAMPS** Steel bar clamps with hinged swivel-plate at foot-end. Clamp can be mounted anyplace — swings in arc of nearly 180° up to or away from the work.	"Regular-service" design, 2" reach. Heavier weight design, medium reach. Light-weight design, deep (3½") reach. Heavier weight design, deep (5") reach.	A new concept in clamp design—"prepositioned" clamps are always ready to swing up to work when wanted—but swing out of the way when not in use. Ideal for making production jigs and fixtures—handy on any bench or saw-horse.
 jaws spacer bar screws side-bars handle	**PILING CLAMPS** ("Stacking" Clamps) Save space (and time) in production gluing by "piling" glued stock.	Screw-operated jaws give *positive* pressure. Each layer of work is clamped from "above" and "below". No "buckling".	No special starting bars, spacers, trucks, etc. required. Most economical method of quantity gluing.

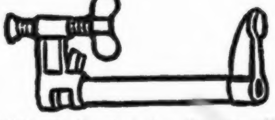
uses ½″ pipe



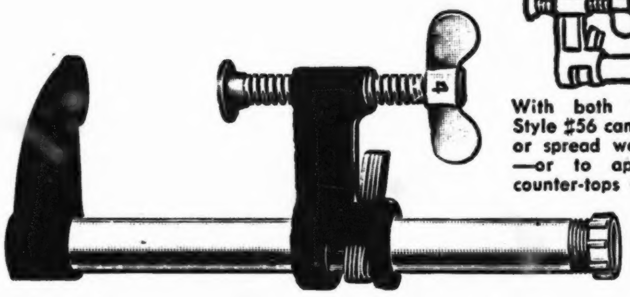


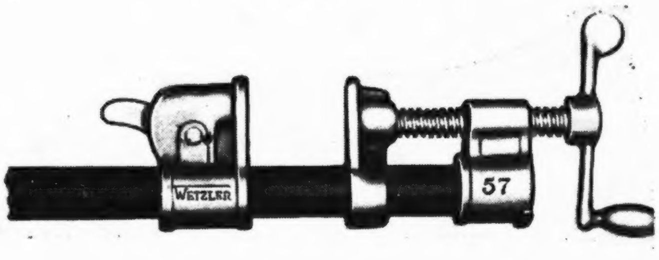


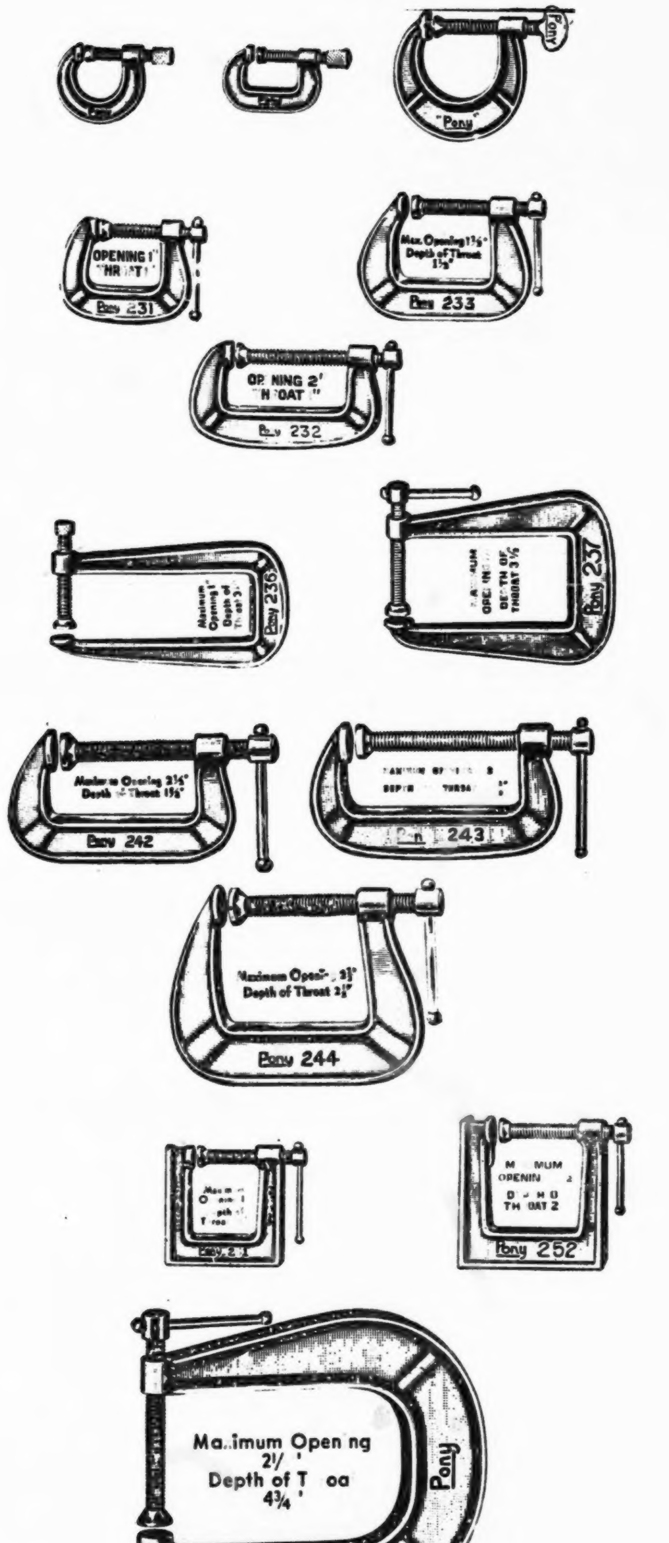
uses ¾″ pipe



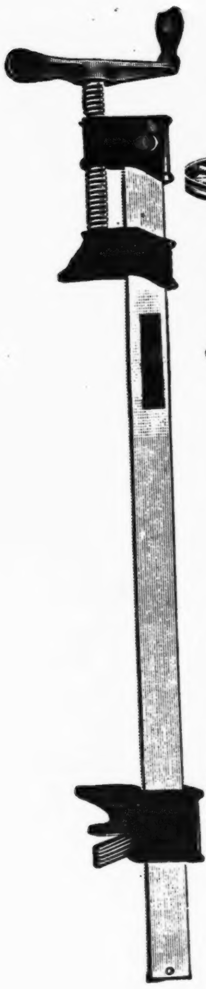
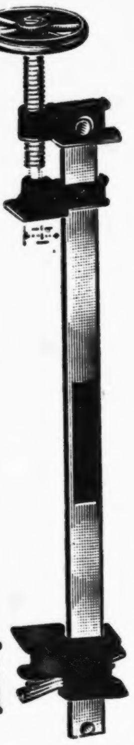
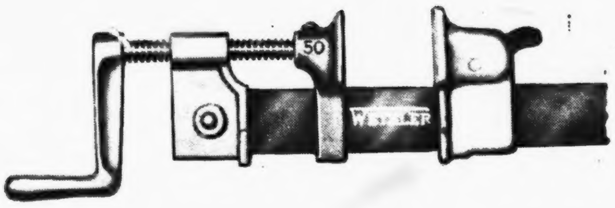
With both heads "reversed", Style #56 can be used to "push" or spread work from the inside —or to apply pressure onto counter-tops under cabinets, etc.

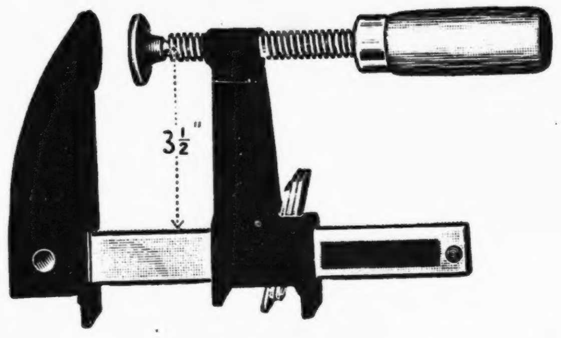


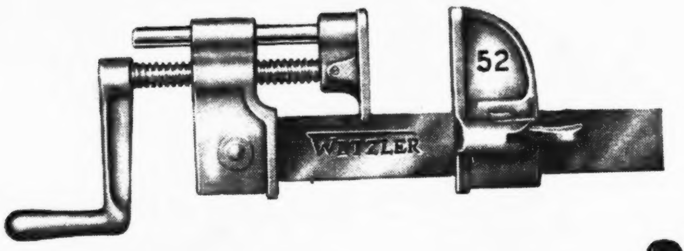


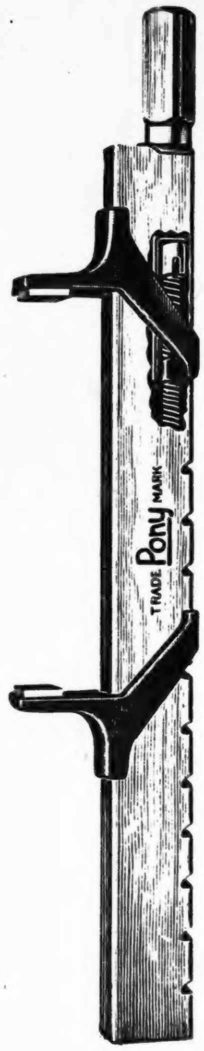
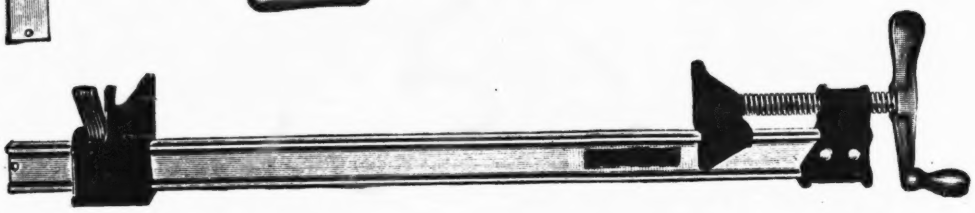

Pony
OPENING 1″ THROAT
Pony 231
Max. Opening 1½″ Depth of Throat 1½″
Pony 233
OPENING 2″ THROAT
Pony 232
Maximum Opening 1″ Depth of Throat 3″
Pony 236
MAXIMUM OPENING DEPTH OF THROAT 3½
Pony 237
Maximum Opening 2¼″ Depth of Throat 1½″
Pony 242
MAXIMUM OPENING DEPTH OF THROAT
243
Maximum Opening 3½″ Depth of Throat 2½″
Pony 244
Pony 251
MAXIMUM OPENING DEPTH OF THROAT 2
Pony 252
Maximum Opening 2½″ Depth of Throat 4¾″
Pony
Maximum Opening 2½″ Depth of Throat 6¼″
Pony

Bar clamps

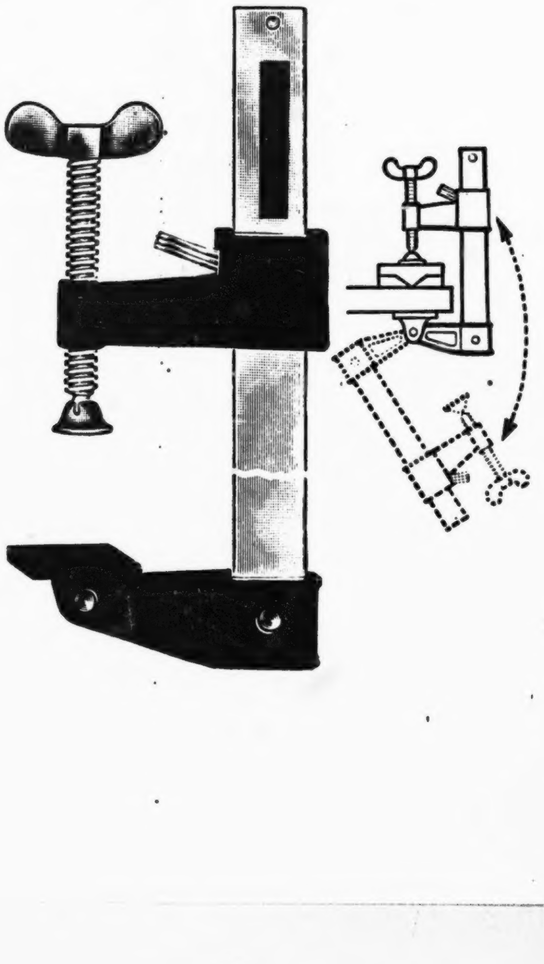





TRADE Pony MARK


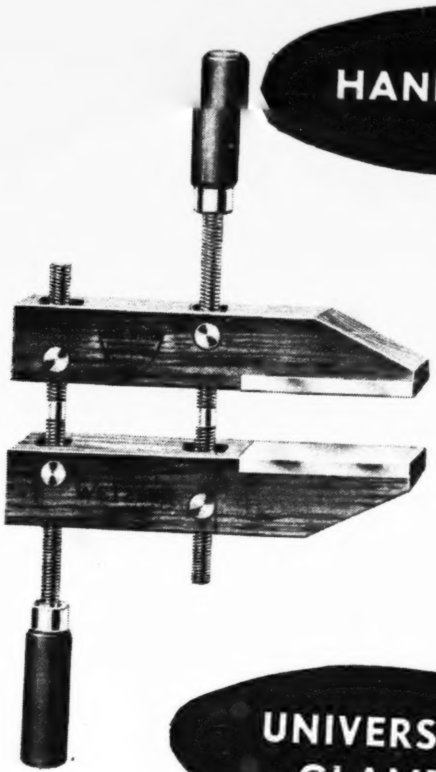
Hinged clamps

Piling clamps

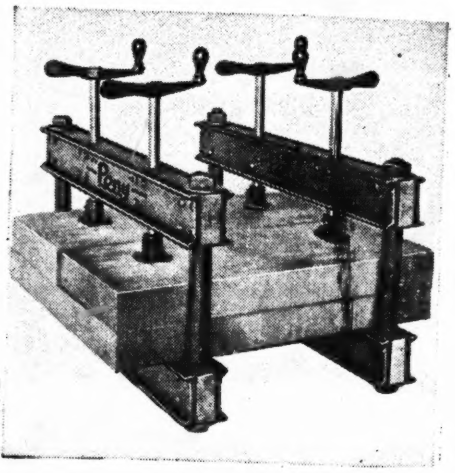


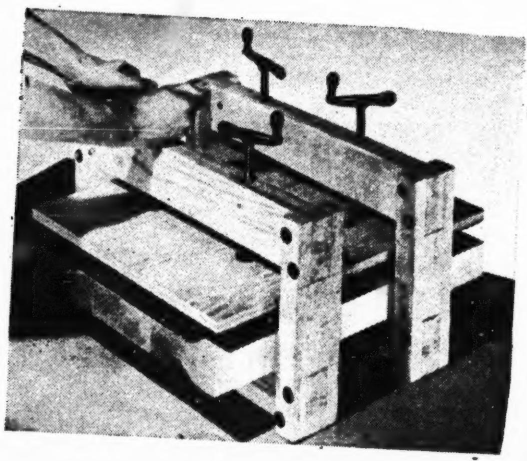
Band clamps

HANDSCREWS

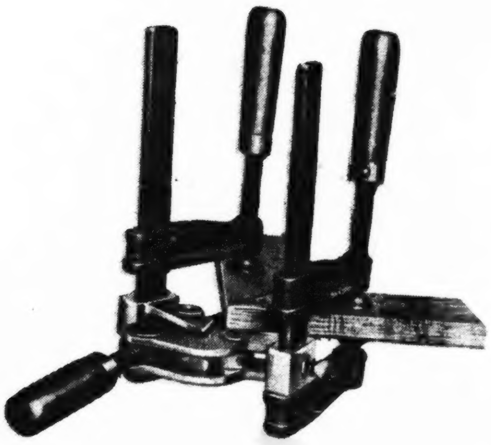


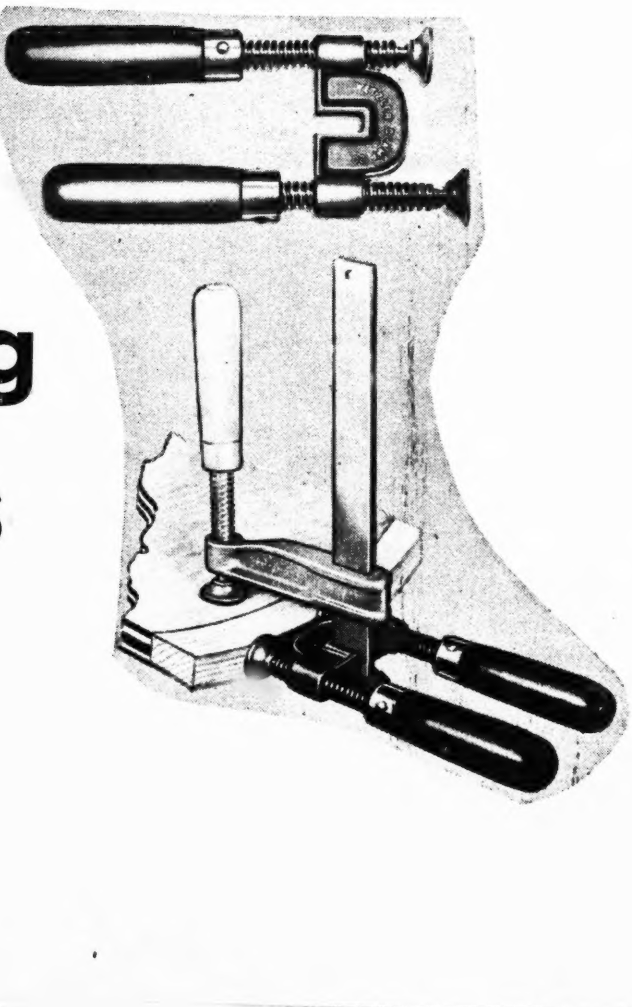
VENEER PRESS FRAMES



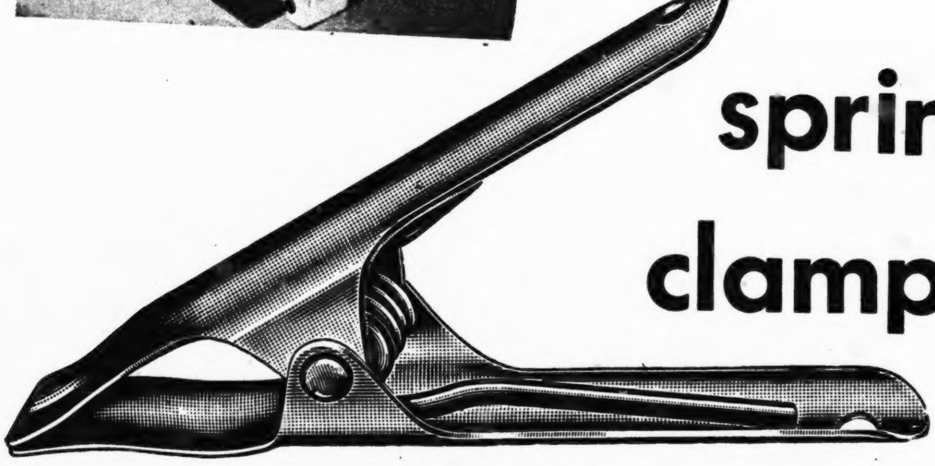


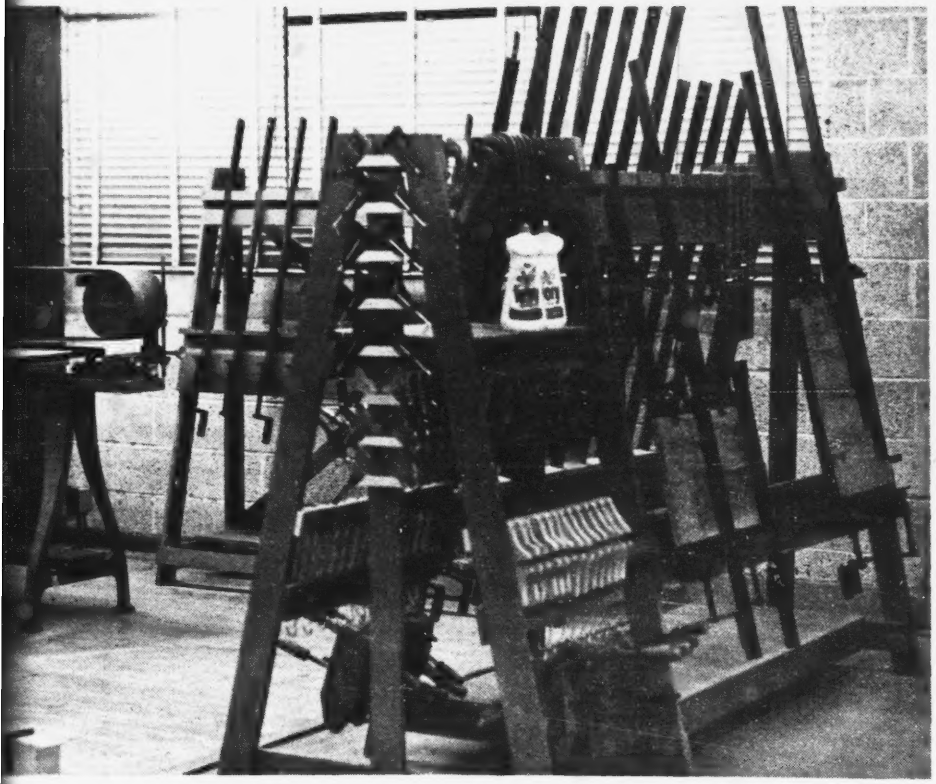
UNIVERSAL CLAMPS

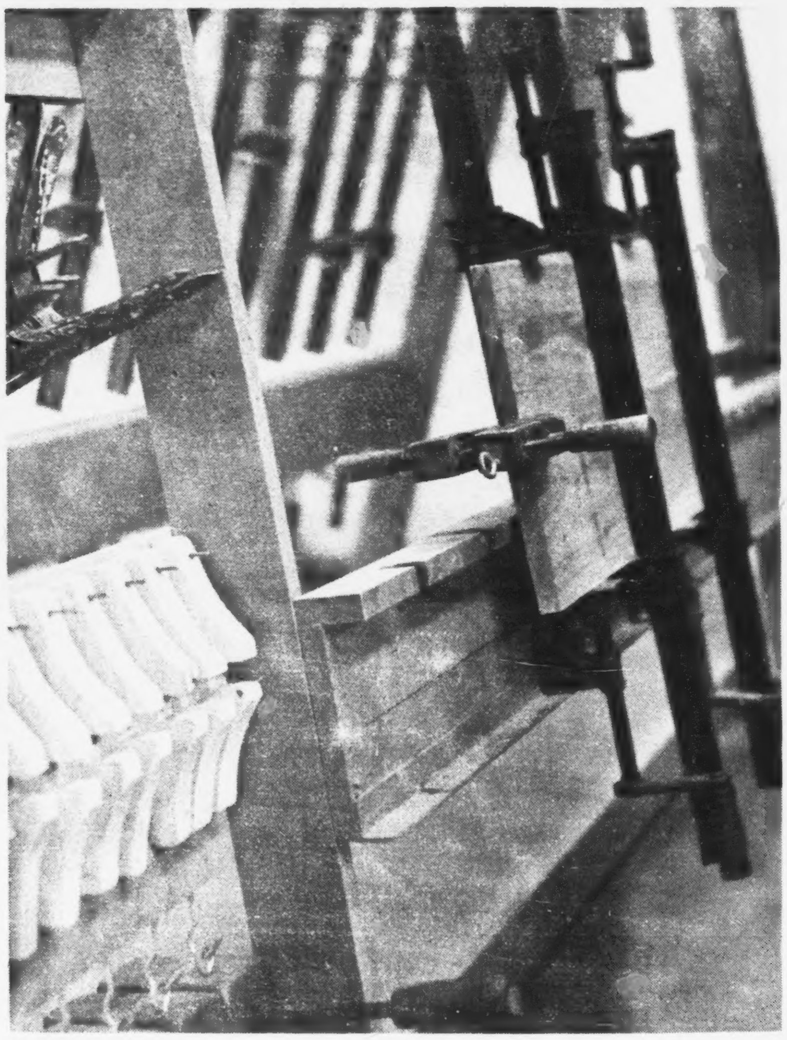




spring clamps







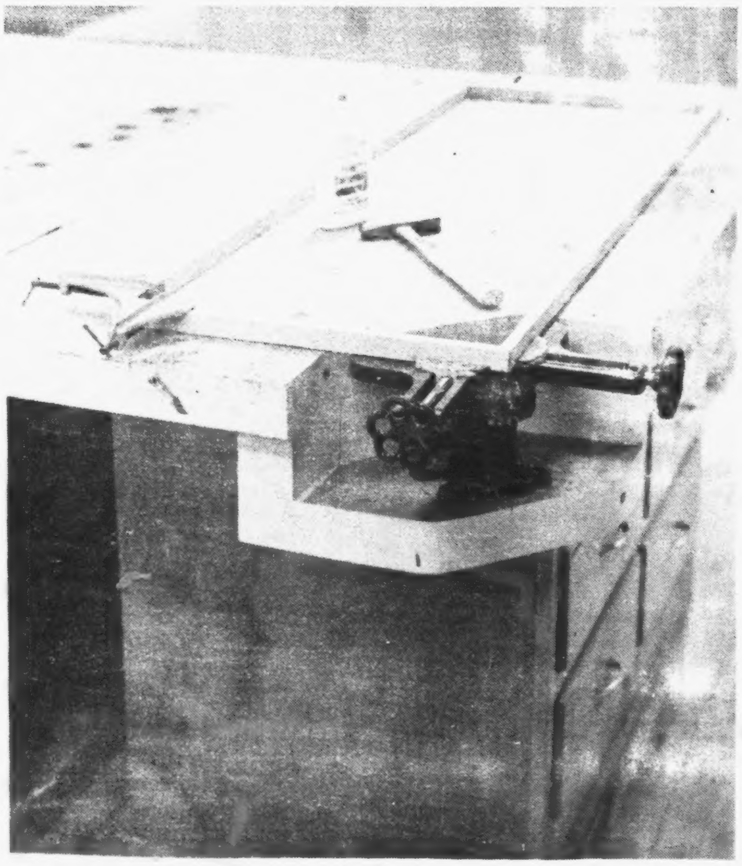
A SPACE SAVING GLUE RACK FOR THE INDUSTRIAL ARTS WOODS LAB

An A-frame structure as shown here will offer approximately twice the edge gluing capacity of a conventional horizontal glue table arrangement within a given amount of floor space.

This arrangement provides for easy inspection of both sides of the glued panel and minimizes clamp handling.

Storage is provided for all clamps used in the woods lab. Note the hook and eye arrangement employed in storing hand screws and the use of discarded liquid detergent bottles for glue application.

The notched blocks shown are used with bar clamps to support and align them on workbench tops when the capacity of the glue rack is exceeded or for special work not adaptable to the vertical rack arrangement.



FLUSH-MOUNTED MITER CLAMP SPEEDS FABRICATION OF PICTURE FRAMES

An extra table can be modified as shown to allow mounting of a Stanley miter clamp with its clamping surface flush with the table top.

This permits the corners of the frame to be joined and shifted with a minimum of stress on the joints.

UNIT III

TESTING OF ADHESIVES

Introduction

The program of research and development in the study of adhesives during the last decade has resulted in the production of adhesives that will satisfy practically any gluing requirement.

Testing adhesives is one of many factors responsible for the far-reaching advances gained in this area of research.

The information presented in the testing unit of this booklet on adhesives has been selected in such a manner that valid testing situations can be organized for effective and purposeful teaching in school laboratories.

Six relatively common methods of testing adhesives are presented in the following pattern of organization:

I. Scope and intent of each test.

II. Specimen specifications.

III. Apparatus necessary to conduct tests.

IV. Procedure in detail

V. Test results

Careful consideration of the details related to each test should result in information comparable to published test results in the adhesive field.

Additional tests can be conducted in the laboratory by referring to available testing data furnished by adhesive manufacturers, forest laboratories or testing agencies. The tests presented here are not conclusive, but do represent the more commonly used methods of measuring adhesive strengths.

Number VII through XI sections of this unit represent somewhat less sophisticated adhesive tests that maybe more easily conducted in industrial education laboratories with limited budgets.

TESTING OF ADHESIVES

I. Delamination

A. Scope

1. This method is an accelerated test intended to determine the resistance of adhesive bonds to delamination on exposure to alternate dry and wet conditions.

   a) Procedure A is intended for testing adhesives used in plywood and wood constructions, although it can be used for other constructions, particularly in sheet form.

   b) Procedure B is intended for testing adhesives in metal or plastic constructions. This procedure is not applicable when the adhesive or the adherend used softens appreciably at temperatures below 100°C. (212°F.).

2. SpecimenII

   a) Test specimen shall be approximately 6 inches by 6 inches by the thickness of the test panel.

   b) When sufficient sample is available, five test specimens shall be cut from each test panel; one shall be cut from each end, approximately at midwidth of the panel, and from each side, approximately at the midlength of the panel, and from somewhere near the center of the panel.

3. Specimen II

   a) Test specimen shall be approximately 0.5 inch wide by 1 inch long by the thickness of the test panel.

   b) Test panels of wood shall be made in accordance with the procedure described in 2.2 of method 1021. (Fed. Test Method Std. No. 175)

   c) Test panels of all other materials, including metals and plastics, shall be prepared for 0.01 inch thick sheets.

   d) Three panels shall be prepared with each adhesive-adhered combination and at least three specimens shall be taken from different parts of each panel.

4. The mixing, weight of spread, method of applying, drying conditions, and assembly time shall be in accordance with the recommendation of the manufacturer.

B. The apparatus shall consist of test tubes, containers, water baths maintained at 60° ± 3° C. (140° ± 5°F.), distilled water with a pH between 5.6 and 7.0, a circulating-air oven maintained at 60° ± 3° C. (140° ± 5°F.), and a mandrel with an 8-inch radius.

C. Procedure

1. Procedure A.

   a) Test specimen I shall be used for this test.

   b) The specimens shall be immersed in water at 23° ± 1.1° C. (73.5° ± 2°F.) for 4 hours, followed by drying at 35° ± 2°C. (96° ± 4°F.) for 20 hours.

   c) The number of cycles to which the specimens shall be subjected shall be specified in the material specification.

2. Procedure B.

   a) Test specimen II shall be used for this test.

   b) The test tubes, one for each specimen, shall be filled with distilled water to a depth of 4 inches, placed in the water bath maintained at boiling, and allowed to come to temperature equilibrium. A test specimen shall then be placed in each tube so that it is completely immersed in the water for 1 hour. At the end of this period, the specimens shall be removed and immersed in distilled water at 23° ± 1.1°C. (73.5° ± 2°F.) for 30 minutes. The specimens shall then be dried at 60° ± 3°C. (140° ±F.) in a circulating-air oven and allowed to cool for 2 hours. The specimens shall then be bent over a mandrel with an 8-inch radius in 3 to 6 seconds until the entire specimen is in contact with the mandrel.

   c) The procedure above shall constitute 1 cycle of the test. The number of cycles to which the specimens shall be subjected shall be specified in the material specification. Unless otherwise specified, 5 cycles shall be used for a complete test.

D. The test report shall include the following data where applicable.

1. Type of specimen and procedure used.

2. Number of cycles to which the specimens were subjected.

3. The pH of the distilled water.

4. The temperature of the bath.

5. Description of the failures as evidenced by delamination, cracking, or splitting of the specimen.

6. Extent of failure.

I I. Peel or stripping strength of adhesives

A. Scope

1. This method of test is intended for use in determining the comparative peel or stripping characteristics of adhesives when tested on standard size specimens and under specified conditions of preparation and testing.

2. Peel or stripping strength is the average load per unit width of bond line required to separate progressively one member from the other over the adhered surfaces at a separation angle of approximately 180° and at a separation rate of 6 inches per minute expressed in pounds per inch of width.

3. The designation "flexible" in this test indicates a material of the proper flexural modulus of elasticity and thickness to permit a turn-vack of an approximate 180° angle by application of a load less than that required to subsequently peel the adherend. At least one of the adherend materials must be flexible.

B. Specimens

1. The test specimen, shown in figure 1A, shall consist of one piece of flexible material, 1 by 12 inches, bonded for 6 inches at one end to one piece of flexible or rigid material, 1 by 8 inches, with the unbonded portions of each member being face to face.

2. To maintain a separation rate of 6 inches per minute, the specimen shall be relatively nonextensible in the expected loading range. Where a material is sufficiently extensible to lessen radically the separation rate, it shall be backed up with a suitable nonextensible material. In reporting such a test, the backing material and method of backing shall be completely identified.

3. Test materials shall be thick enough to withstand the expected tensile pull. Wherever possible, the standard thickness or weight of adherend material used to make the specimens shall be: metals, 1/16"; plastics, 1/16"; woods, 1/8"; rubber compounds, 0.075 inch; and cotton duck, 30 ounce per square yard. Other special materials, as well as the standard materials, shall be completely identified in the test report.

4. At least 10 test specimens shall be tested for each adhesive.

5. Any specimen whose test result is out of line because of some obvious flaw shall be discarded and retest made.

6. All bonding shall be done in accordance with the procedure and recommendations outlined by the manufacturer of the adhesive.

7. While individual specimens may be prepared, it is recommended where possible, that specimens be cut from bonded panels approximately 6 inches in width as shown in figure 1B, so that five standard 1-inch wide specimens may be obtained from each panel.

8. All specimens shall be conditioned for 7 days by exposure to a relative humidity of 50 ± 4 per cent at $23^{\circ} \pm 1.1^{\circ}$C. ($73.5^{\circ} \pm 2^{\circ}$F.) or until equilibrium is reached.

C. Apparatus

1. The tests shall be made with a power-driven machine, which shall fulfill the following requirements:

   a) The applied tension as measured and recorded shall be accurate within plus or minus 1 per cent.

   b) Specimens shall be held in the testing machine by grips that clamp firmly and prevent slipping at all times.

   c) The rate of travel of the power-actuated grip shall be 12 inches per minute. This rate, which provides a separation of 6 inches per minute shall be uniform throughout the tests.

d) The machine shall be operated without any device for maintaining maximum load indication. In pendulum-type machines, the weight lever shall swing as a free pendulum without engagement of pawls.

e) The machine shall be autographic, giving a chart having the inches of separation as one axis and applied tension as the other axis of coordinates.

f) The machine shall be of such capacity that the maximum applied tension during test shall not exceed 85 per cent nor be less than 15 per cent of the rated capacity.

2. Conditioning room or desiccators are necessary. A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent of $23^\circ \pm 1.1^\circ$ C. ($73.5^\circ \pm 2^\circ$ F.), or desiccators filled with a saturated salt solution (note 1) to give a relative humidity of 50 ± 4 per cent at $23^\circ \pm 1.1^\circ$C. ($73.5^\circ \pm 2^\circ$F.) are required for the conditioning of such specimens. (Note 1, Refer to II - D. - 5)

D. Procedure

1. Tests shall be conducted as soon as possible after removal of the test specimens from the conditioning atmosphere and preferably under the same conditions.

2. The free end of the 1-inch-wide flexible member shall be separated by hand from the other member for a distance of about 1 inch. The specimen shall then be placed in the testing machine by clamping the free end of the 8-inch-long member in one grip, turning back the free end of the flexible member, and clamping it in the other grip as shown in figure 2. Care shall be used to adjust the specimen symmetrically in order that the tension shall be distributed uniformly. Provision shall be made to maintain the specimen during test approximately in the plane of the clamps. This may be done either by attaching the minimum weight required to the free end of the specimen or by holding the specimen against an alinement plate (fig. 2) attached to the stationary clamp. In either case, the added weight shall be taken into account in determining the load causing separation. The 1-inch wide flexible member shall be gripped symmetrically and firmly without twisting in the power-actuated clamp. The autographic mechanism and chart shall be adjusted to zero and the machine started. The separating member shall be stripped from the specimen approximately at an angle of 180° and the separation continued for a sufficient distance to indicate the peel or

stripping value. At least one-half of the bonded area shall be peeled even thugh a peel or stripping value may be indicated before this point.

3. The actual peel or stripping strength shall be determined by drawing on the autographic cahrt the best average load line which will accommodate the recorded curve. The load so indicated, corrected for any tare weight which may have been used with the specimen as described in D-2, expressed in pounds per inch of width for separation at 6 inches per minute, shall be reported as the peel or stripping strength for the particular specimen under test.

4. For each series of tests, the arithmetic mean of the values obtained shall be calculated and reported as the average value. The standard error, s, of the reported average value shall be calculated as follows:

$$s = \sqrt{\frac{\sum x^2 - N x^{-2}}{N(N-1)}}$$

where: s = standard error of the average,
x = value of a single observation,
N = number of observations, and
$\bar{x}$ = arithmetic mean of the set of observations.

5. A saturated solution of calcium nitrate will give approximately 52 per cent relative humidity at 23°C.

6. Cohesion or adhesive failure may be determined by observation. A cohesive failure is one which has occurred in the adhesive or specimen material itself. Adhesive failure refers to the lack of adherence to the materials being bonded.

E. The test report shall include the following data where applicable:

1. Method of preparing test specimens.

2. Testing room conditions.

3. Number of specimens tested.

4. Identity and thickness of adherends.

5. Rate of loading.

6. Average value and standard error of peel or stripping strength.

7. Maximum and minimum strength values of the series.

8. Individual test values, individual autographic charts, and other statistical data as specified by the material specification.

9. Type of failure; whether in adhesion, cohesion in the adhesive, or in the material being bonded.

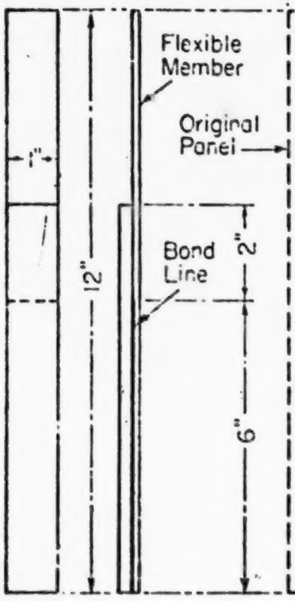

1"
12"
Flexible Member
Original Panel
2"
Bond Line
6"

Figure 1a.—*Test specimen.*

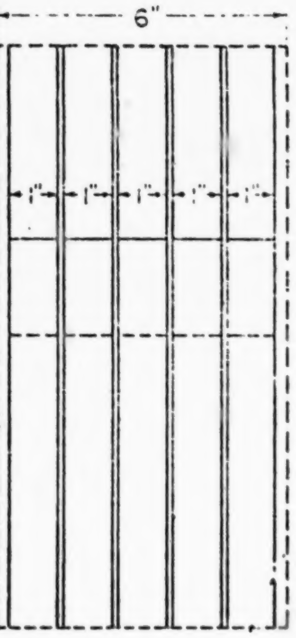


Figure 1b.—*Specimens from bonded panel.*

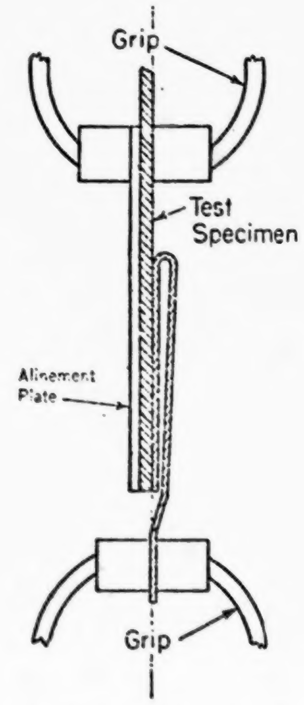

Grip
Test Specimen
Alinement Plate
Grip

Figure 2.—*Specimen under test*

III. Resistance of Adhesive bonds to water (wet strength)

A. Scope

1. This method of test is intended for use in determining the wet strength values of adhesives used in assemblies, when tested on a standard specimen and under specified conditions of preparation, conditioning, and testing. The procedures are intended primarily for adhesives used in bonding wood, although they may be used for other constructions.

2. The test specimens shall be identical with those required in the method of test for the strength properties to be measured or as specified in the material specification.

B. Apparatus

1. The apparatus shall consist of suitable containers for test specimens and a cabinet or room for maintaining a temperature of 23° ± 1.1° C. (73.5° ± 2° F.).

2. Apparatus for making the strength tests is specified in the method for the property to be measured.

3. Unless otherwise specified, distilled water with a pH between 5.6 and 7.0 shall be used for the tests.

4. Water bath maintained at boiling (97° to 100° C.).

C. Procedure

1. In the continuous immersion test, the test specimens shall be immersed in distilled water for 48 ± 2 hours and the strength test made immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers. The temperature of the water shall be maintained at 23° ± 1.1° C. (73.5° ± 2° F.).

2. In the water boil test, the test specimens shall be immersed in boiling water (97° to 100° C.) for 3 hours ± 10 minutes, removed and immersed in water at 23° ± 1.1° C. (73.5° ± 2° F.) and o.5 hour ± minutes and then tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

3. In the wet and dry cyclic test, the test specimen shall be subjected to the following cycles of conditions:

Cycle	Period	Temperature	Wet condition
	Hours	° *C.*	
1	48	23±1.1	Immersion in water.
	8	60±3	Less than 10 percent relative humidity.
2	16	23±1.1	Immersion in water.
	8	60±3	Less than 10 percent relative humidity.
3	16	23±1.1	Immersion in water.
	8	60±3	Less than 10 percent relative humidity.
4	16	23±1.1	Immersion in water.

The specimens shall be tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container, but specimens from different samples shall be immersed in separate containers.

4. In the water boil and dry cyclic test, the test specimen shall be subjected to the following cycles of conditions:

Cycle	Period	Temperature	Wet condition
	Hours	° *C.*	
1	4	97–100	Immersion in boiling water.
	20	60±3	Less than 10 percent relative humidity.
2	4	97–100	Immersion in boiling water.
	4	23±1.1	Immersion in water.

The specimens shall be tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container, but specimens from different samples shall be immersed in separate containers.

5. In the vacuum-pressure accelerated wet and dry cyclic test, the test specimen shall be subjected to the following cycles of conditions:

Cycle	Period	Wet or dry condition	Pressure
	Hours		
1	2	Dry	Vacuum of 20–25 inches of mercury.
2	2	Immersed in water	75 lb./in.^{2}.
	2	do	Vacuum of 20–25 inches of mercury.
3	2	do	75 lb./in.^{2}.
	16	do	Atmospheric.
	144	In circulating air at 26° C. and 30 percent relative humidity.	Do.

This procedure shall be repeated twice, making a test of 21 days duration. The specimens shall be tested immediately. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

D. The test report shall include the following data where applicable.

1. Complete identification of the adhesive tested including type, source, manufacturer's code numbers, for, etc.

2. Application and bonding conditions used in prepartıng the specimens.

3. Conditioning procedure used for the specimens.

4. The procedure or procedures used.

5. Number and size of specimens tested in each procedure.

6. Number of panels represented.

7. Maximum and minimum loads at failure and percentages of aherend failure values may be included in the report if specified by the material specification.

8. The average load at failure and the average percentage of wood failure.

9. Extent of delamination.

IV. Shear Strength Properties of Adhesives by Compression Loading

A. This method of test is intended for determining the comparative shear strengths of adhesives, used for bonding wood and other similar materials, when tested on a standard specimen under specified co ndtions of preparation, conditioning, and loading in in compression. This method is intended primarily as an evaluation of adhesives for wood.

B. Specimens

1. Test specimens shall conform to the form and dimensions shown in figure 1.

2. At least 10 specimens shall be tested, representing at least 2 different joints.

3. Hard maple blocks (Acer saccharum or Acer nigrum), having a minimum specific gravity of 0.65 based on oven-dry weight and volume shall be selected (note 1). These blocks shall be straight grain and free from defects including knots, birdseye, short grain, decay, and anyunusual discolorations within the shearing area. The blocks shall be of suitable size, preferably so that five test specimens may be cut from one test joint as shown in figure 2. Blocks approximately 3/4 by 2 1/2 by 12 inches have been found to be found to be satisfactory for this purpose. The grain direction shall be parallel to the longest dimension of the block. The blocks shall be at the equilibrium moisture content recommended by the manufacturer of the adhesive. In the absence of such recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples (note 2). The blocks shall be surfaced, just prior to bonding, preferably with a hand-feed jointer, and the blocks weighed and assembled in pairs so that blocks of approximately the same specific gravity are bonded together. The surfaces shall remain unsanded and shall be free from dirt.

4. The adhesive shall be prepared and applied to the blocks in accordance with the procedure recommended by the manufacturer of the adhesive. If no rate of spread is recommended, 3 to 4 grams of adhesive mix shall be applied to each contacting surface. The adhesive-coated blocks shall then be assembled and pressed, likewise in accordance with the recommendations of the manufacturer of the adhesive.

5. The specimens shall be cut as shown in figure 2 so that the grain direction is parallel to the direction of leading during test. Care shall be taken in preparing the test specimens to make the loaded surfaces smooth and parallel to each other and perpendicular to the height. When sawing the bonded assembly into five separate test specimens, care shall also be exercised in reducing the lengths of the laminations to 1 3/4 inches to insure that the saw cuts extend to, but not beyond, the adhesive line. The width and height of the specimen at the adhesive line shall be measured to the nearest 0.010 inch to determine the shear area.

6. Specimens shall be retained in the conditioning atmosphere.

C. Apparatus

1. The testing machine shall be fitted with a compression shearing tool containing a self-aligning seat to insure uniform lateral distribution of the load.

2. The machine shall be capable of maintaining a uniform rate of grip separation such that the load may be applied with a continuous motion of the movable head to maximum load at a rate of 0.015 inch per minute with a permissible variation of plus or minus 25 per cent.

3. The shearing tool shown in figure 3 has been found satisfactory.

4. The testing machine shall be located in an atmosphere such that the moisture content of the specimens developed under the conditions prescribed in D-1 is not noticeable altered during testing.

D. Procedure

1. The joints upon removal from pressure shall be conditioned at a relative humidity of 50 ± 4 per cent (note 3) and at a temperature of 23° ± 1.1°C. (73.5° ± 2° F.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. The length of this period of conditioning may be extended beyond this limit in the material specifications.

2. The test specimen shall be placed in the shearing tool so that the load may be applied as described in C-1. The position of the specimen in one type of shearing tool is shown in figure 3. The loading shall be applied with a continuous motion of movable head at a rate of 0.015 inch per minute to failure as prescribed in C-1.

3. The shear stress at failure shall be calculated in pounds per square inch, based on the adhesive line area between the two laminations measured to the nearest 0.01 square inch, and shall be reported for each specimen together with the estimated percentage of wood failure.

Note 1. - A convenient method for determining the specific gravity of blocks of wood will be found in section 115 of the Tentative Methods of Testing Small Clear Specimens of Timber (A. S. T. M. designation: D 143-52) of the American Society for Testing Materials.

Note 2. - Convenient methods for determining the moisture content by oven drying procedures will be found either in sections 122 to 125 of the Tentative Methods of Testing Small Clear Specimens of Timber (A. S. T. M. designation: D 143-52) of the American Society for Testing Materials or in Military Specification MIL-W-6110 for Determination of Moisture Content of Wood.

Note 3. - A saturated solution of calcium nitrate will give approximately 52 per cent relative humidity at 32°C.

E. The test report shall include the following data where applicable.

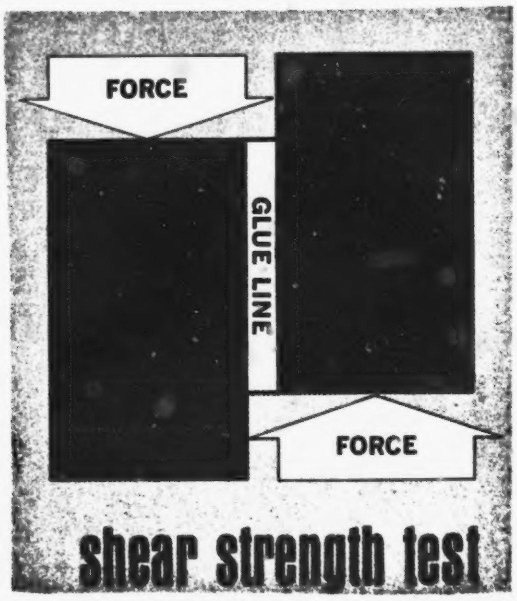
1. Application and bonding conditions used in preparing the specimens.

2. Temperature and relative humidity in the test room.

3. Number of specimens tested.

4. Maximum and minimum shear stresses at failure and percentages of wood failure. The standard deviation or all individual test values, or both, for the failing load values and wood failure values may be included in the report, as specified in the material specification.

5. The average shear stress at failure and the average percentage of wood failure.


FORCE
GLUE LINE
FORCE
shear strength test

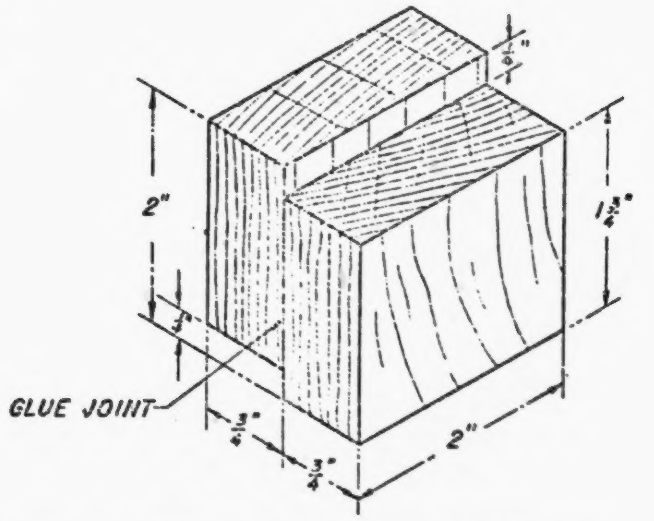

1/4"
2"
1 3/4"
3/4"
GLUE JOINT
3/4"
3/4"
2"

FIGURE 1.—*Form and dimensions of test specimen.*

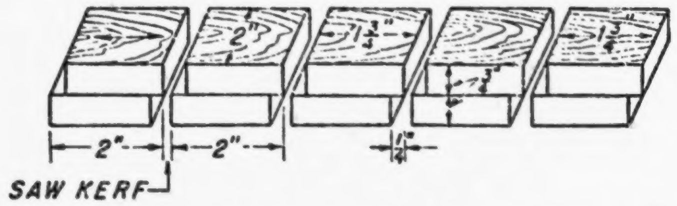

2"
1 3/4"
3/4"
1 3/4"
2"
2"
1/4"
SAW KERF

FIGURE 2.—*Test joint showing method of cutting five test specimens.*

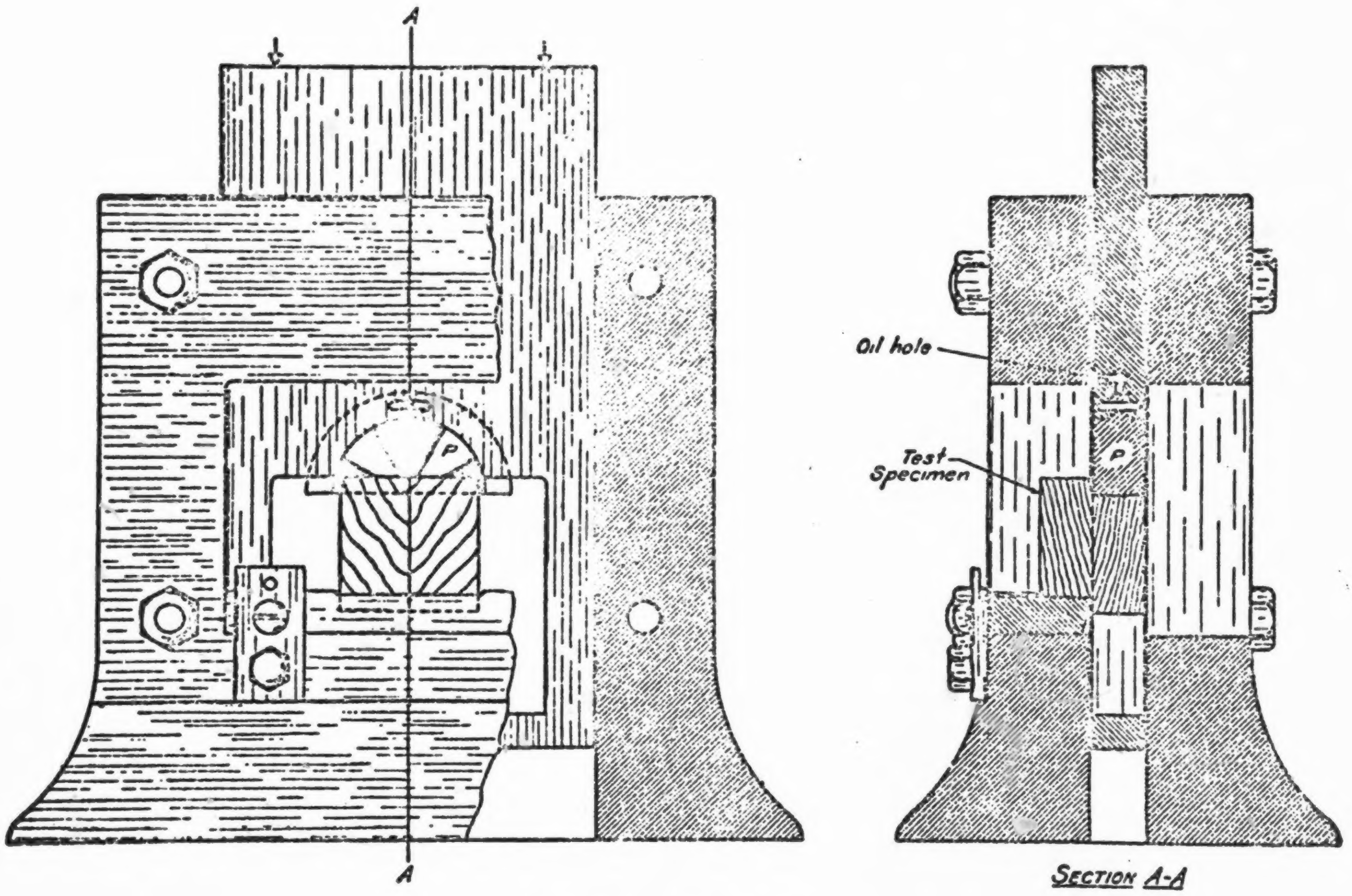

A
A
Oil hole
Test Specimen
P
P
Section A-A

Figure 3. *Shearing tool.*

V. Shear strength properties of adhesives determined with single-lap constructions by tension loading.

A. Scope

1. This method of test is intended for use in determining the comparative shear strengths of adhesives for bonding adherends when tested on a standard specimen and under specified conditions of preparation and testing.

2. A variation in thickness of the adherends will likely influence the test values. For this reason, the thickness of the sheets used to made the test specimen shall be specified in the material specification. When no thickness is specified, sheets of adherends 0.064-inch thick are recommended.

B. Specimens

1. The test specimens shall conform to the form and dimensions shown in figure 1.

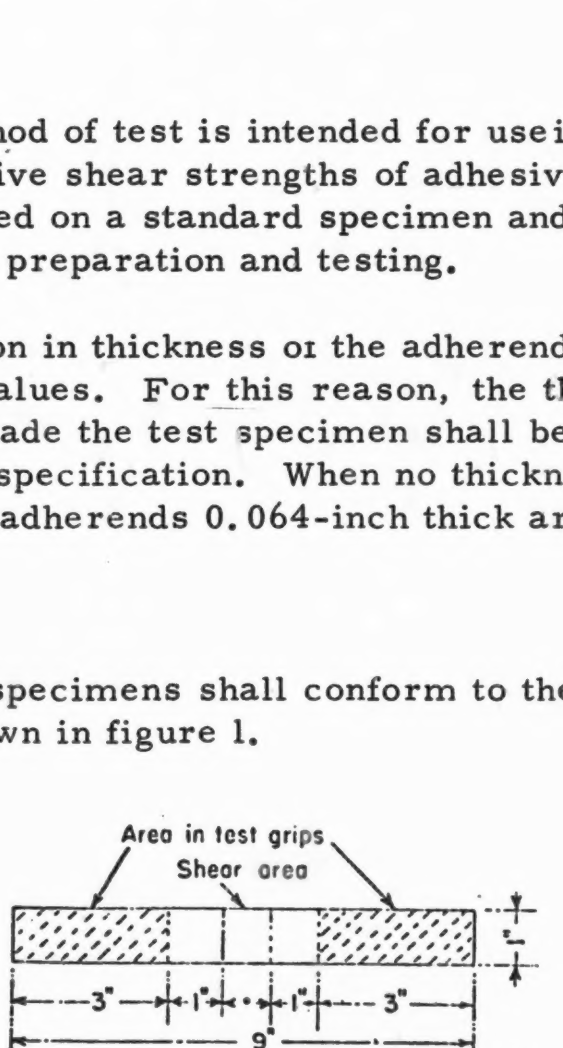

Area in test grips
Shear area
1"
3"
1"
*
1"
3"
9"
Adhesive
.064"
*Overlap as specified in 2.5

Figure 1.—*Specimen placement for shear strength test.*

2. At least 20 specimens shall be tested, representing at least four different panels.

3. Sheets of the adherend materials (metal, wood, plastic, etc.) shall be cut to 6-by 6-inch squares. The sheets shall be cleaned and dried carefully according to the procedure prescribed by the manufacturer and assembled into the specified pairs. When wood is used, the moisture content shall be a value recommended by the manufacturer of the adhesive. In the absence of such a recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples (note 1).

4. The adhesive shall be prepared and applied, in accordance with the recommendations of the manufacturer of the adhesive to an area 0.25 inch wider than the overlap to be used and 6 inches long across the end of one or both sheets of each pair. The sheets shall then be assembled and held rigidly so that the length of the overlap shall be as calculated in 2.5 and the adhesive allowed to cure as prescribed by the manufacturer of the adhesive.

5. The length of the overlap shall be based on the thickness of material being bonded. The ratio of $\sqrt{\frac{t}{L}}$ shall be 0.5 or greater for metal specimens where t is the thickness of the adherend in inches and L the overlap in inches. For nonmetallic materials, the overlap shall be 1 inch for adherends 1/8 inch or thicker and 1/2 inch for adherends less than 1/8 inch thick.

6. Test specimens, as shown in figure 1, shall be cut from the joints. This cutting operation must be done so as to avoid overheating or mechanical damage to the bonds. The width of the specimen and the length of the overlap shall be measured to the nearest 0.010 inch to determine the shear area.

7. The finished specimens shall be conditioned at a relative humidity of 50 ± 4 per cent and at a temperature of $23^{\circ} \pm 1.1^{\circ}$ C. ($73.5^{\circ} \pm 2^{\circ}$ F.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. The length of this period of conditioning may be extended beyond this limit in the material specification.

8. Specimens shall be retained in the conditioning atmosphere until tested.

2. At least 20 specimens shall be tested, representing at least four different panels.

3. Sheets of the adherend materials (metal, wood, plastic, etc.) shall be cut to 6-by 6-inch squares. The sheets shall be cleaned and dried carefully according to the procedure prescribed by the manufacturer and assembled into the specified pairs. When wood is used, the moisture content shall be a value recommended by the manufacturer of the adhesive. In the absence of such a recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples (note 1).

4. The adhesive shall be prepared and applied, in accordance with the recommendations of the manufacturer of the adhesive to an area 0.25 inch wider than the overlap to be used and 6 inches long across the end of one or both sheets of each pair. The sheets shall then be assembled and held rigidly so that the length of the overlap shall be as calculated in 2.5 and the adhesive allowed to cure as prescribed by the manufacturer of the adhesive.

5. The length of the overlap shall be based on the thickness of material being bonded. The ratio of $\sqrt{\frac{t}{L}}$ shall be 0.5 or greater for metal specimens where t is the thickness of the adherend in inches and L the overlap in inches. For nonmetallic materials, the overlap shall be 1 inch for adherends 1/8 inch or thicker and 1/2 inch for adherends less than 1/8 inch thick.

6. Test specimens, as shown in figure 1, shall be cut from the joints. This cutting operation must be done so as to avoid overheating or mechanical damage to the bonds. The width of the specimen and the length of the overlap shall be measured to the nearest 0.010 inch to determine the shear area.

7. The finished specimens shall be conditioned at a relative humidity of 50 ± 4 per cent and at a temperature of 23° ± 1.1° C. (73.5° ± 2° F.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. The length of this period of conditioning may be extended beyond this limit in the material specification.

8. Specimens shall be retained in the conditioning atmosphere until tested.

C. Apparatus

1. The testing machine shall be capable of maintaining a rate of loading of 600 to 700 pounds per square inch per minute.

2. It shall be provided with suitable grips and jaws so that the specimen can be gripped tightly and held in alignment as the load is applied.

D. Procedure

1. Dry test - The specimens shall be tested in an atmosphere maintained at 50 ± per cent relative humidity and 23° ± 1.1° C. (73.5° ± 2° F.).

2. Wet test - The test specimens shall be subjected to one or more of the procedures given in section III (Resistance of Adhesive Bonds to Water) if wet strength values are required.

3. The test specimen shall be placed in the jaws of the grips tightly so that the specimen is perfectly aligned and the jaws are directly above each other and in such a position that an imaginary straight vertical line would pass through the center of the bonded area and through the points of suspension. The load shall then be applied at a rate of 600 to 700 pounds per square inch per minute until failure (such as cohesion in adherend, or adhesion) shall be recorded for each specimen.

4. The load at failure shall be recorded. All failing loads shall be expressed in pounds per square inch of shear area, calculated to the nearest 0.01 square inch. The nature and amount of the failure (such as cohesion in adherend, or adhesion) shall be recorded for each specimen.

E. The test report shall include the following date where applicable.

1. The complete identification of the adherends used, their thickness, and the methods of cleaning, and preparing their surfaces prior to bonding.

2. Application and bonding conditions used in preparing the specimens.

3. Number of specimens tested.

4. Number of panels represented.

5. Temperature and relative humidity in the test room.

6. Maximum and minimum loads at failure and percentages of wood failure, if any. The standard deviation or all individual test values, or both, for the failing load values and wood failure values may be included in the report as requested in the material specification.

7. The average load at failure and the average percentages of failure in cohesion or adhesion.

Note 1. A convenient method for determining the moisture content of wood will be found in sections 122 - 125 of the Tentative Methods for Testing Small Clear Specimens of Timber (ASTM designation: D 143-52) of the American Society for Testing Material.

VI. Shear strength properties of adhesion in plywood type construction by tension loading.

A. Scope

1. This method of test is intended for determining the comparative sher strengths of adhesives in plywood-type construction when tested on a standard specimen and specified conditions of preparation, conditioning, and testing. This method is intended to be applied only to adhesives used in bonding wood to wood.

2. The requirements in the material specification will indicate whether or not both the dry and wet tests shall be made. The procedure for the wet tests shall be specified from Section III

B. Specimens

1. The test specimen shall conform to the form and dimensions shown in figure 1.

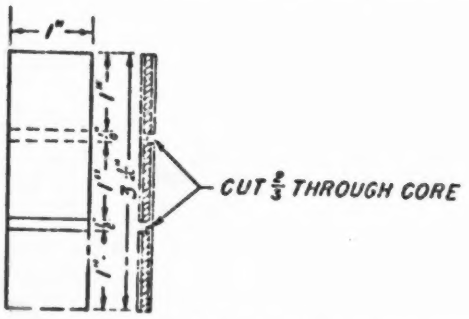


FIGURE 1. —Form and dimensions of test specimen.

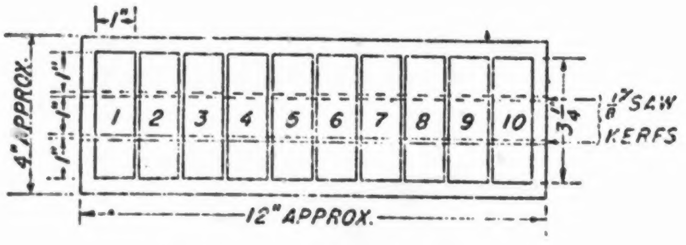


FIGURE 2.—Size of test panel.

2. At least 20 specimens shall be tested, representing at least four different panels for the dry test and a like number for wet test.

3. Sweet or yellow birch veneer (Betula lenta or Betula lutes), either rotary cut or sliced, 1/16 inch in thickness, shall be selected so that it is free from defects such as knots, cracks, short grain, or any unusual amount of discoloration which would indicate decay. The surfaces shall be unsanded. The veneer shall be cut into suitable sizes and assembled in groups of three sheets, the grain of the center sheet running at right angles to the grain of the other two sheets. The grain in all sheets shall be parallel to one edge. A size which has been found to be convenient is shown in figure 2, in which case the grain in the face ply should be parallel to the shorter dimension. The veneer shall be at the moisture content recommended by the manufacturer of the adhesive. In the absence of such a recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry-weight as determined on representative samples in the material specification. Any other species of veneer may be designated by the material specification.

4. The adhesive shall be prepared in accordance with the procedure outlined by the manufacturer of the adhesive.

5. The adhesive shall be applied to the veneers as prescribed by the manufacturers of the adhesive. After the prescribed time has elapsed, the veneers shall be assembled into three-ply panels so that the grain in the center ply is at right angles to the grain in the two outer plies. The panel shall then be bonded in accordance with the recommendations of the manufacturer of the adhesive.

6. The panels, after bonding, shall be aged in accordance with the recommendations of the manufacturer of the adhesive.

7. The test specimens shall be cut as shown in figure 1. This is best accomplished by cutting the notches to the proper width, depth, and location in the test panel, using a hollow ground grooving saw or any other method that will give equally satisfactory results. The individual test specimens shall then be cut from the panel. The cutting of individual specimens is shown for one size of panel in figure 2. The width of the specimen and the distance between notches shall be measured to the nearest 0.010 inch to determine the shear area.

C. Apparatus

1. The testing machine shall be capable of maintaining a rate of loading of 600 to 700 pounds per square inch per minute.

2. It shall be provided with suitable grips and jaws so that the specimen can be gripped tightly and held in alignment as the load is applied.

3. The grips and jaws shown in figure 3 have been found satisfactory.

D. Procedure

1. The finished specimens shall be conditioned at a relative humidity of 50 ± 4 per cent and at a temperature of 23° ± 1.1°C. (73.5° ± 2° F.) either for 7 days or until the specimens reach equilibrium as indicated by no progressive changes in weight, which ever is the shorter period. The length of this period may be extended beyond this limit in the material specification.

2. Dry test - The specimens shall be tested in an atmosphere maintained at 50° ± 4 per cent relative humidity and 23° ± 1.1° C. (73.5° ± 2° F.).

3. Wet test - The test specimens shall be subjected to one or more of the procedures given in Section III if wet strength values are required.

4. The test specimen shall be placed in the jaws of the grips in the testing machine and gripped tightly so that the specimen is perfectly aligned and the jaws are directly above each other and in such a position that an imaginary straight vertical line would pass through the center of the bonded area and through the points of suspension A and B, as shown in figure 3. Specimens shall be placed in the jaws alternately so that in one case the upper notch is to the left and in the other case toward the right. The load shall then be applied at a rate of 600 to 700 pounds per square inch per minute until failure.

5. The load at failure and the estimated per cent of wood failure shall be recorded for each test specimen. All failing loads shall be expressed in pounds per square inch of shear area, calculated to the nearest 0.01 square inch.

Note 1 - Convenient methods for determining the moisture content by oven drying procedures will be found either in sections 122 to 125 of the Tentative Methods for Testing Small Clear Specimens of Timber (A.S.T.M. designation: D 143-52) of the American Society for Testing Materials or in Military Specification MIL-W-6110 for determination of moisture content of wood.

Note 2 - By making three-ply panels with other materials, such as wood and metal, adhesives for other materials may be tested by this method.

E. The test report shall include the following date where applicable:

1. Application and bonding conditions used in preparing the specimens.

2. Temperature and relative humidity in the test room.

3. Number of specimens tested.

4. Number of panels represented.

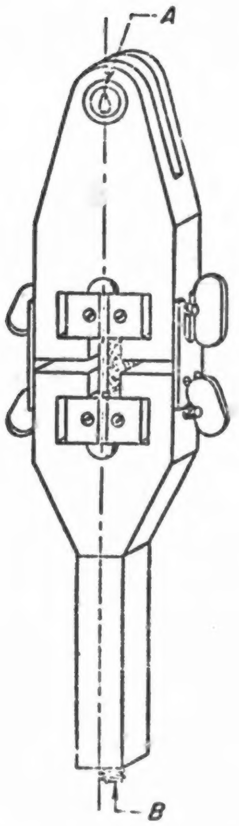
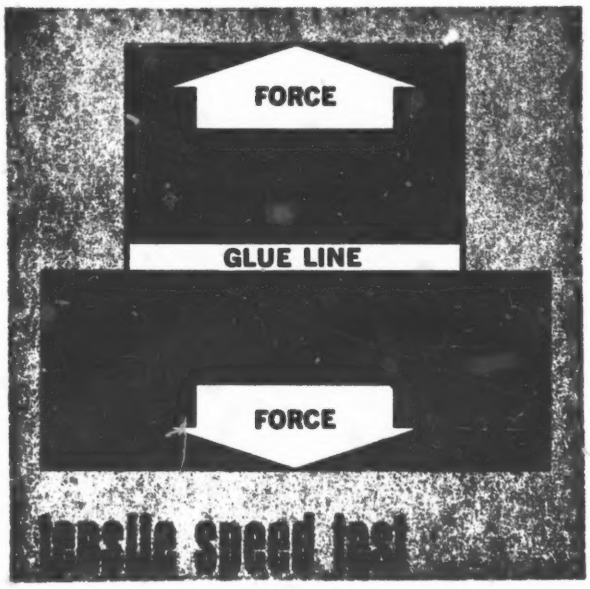
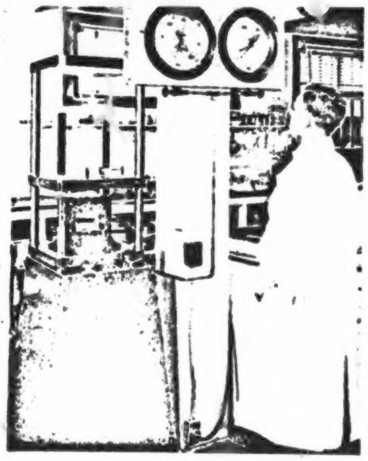


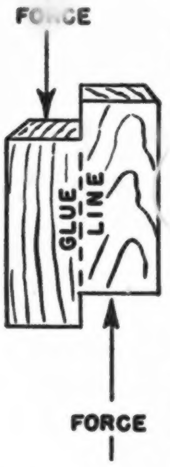
FIGURE 3.--Grips and jaws.



How Wood Adhesives Are Tested



Compression Block Shear Tester



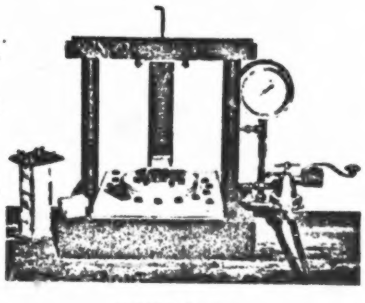
THE BLOCK SHEAR TEST

The compression block shear test is the most commonly used test for evaluation of wood glues suitable for high stress applications such as assembly gluing, lumber laminating, edge gluing, and similar applications.

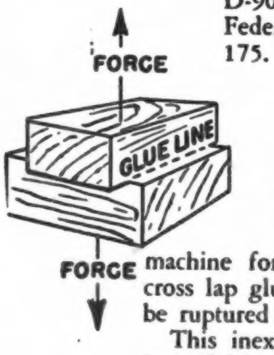
Hard maple blocks, as shown in the drawing, are prepared under carefully controlled gluing conditions and are tested by slowly applying a compressive force to the end of the block held in the testing jig.

The shearing force required to break such a specimen bonded with a high quality glue may run as high as 3,000-4,000 psi or a total shear strength of 9,000 - 12,000 pounds for each block 3 square inches in area.

The shear block test procedure is fully described in ASTM Procedure D-905-49 or in Method 1031 of Federal Test Method Standard No. 175.



NAFM Tester

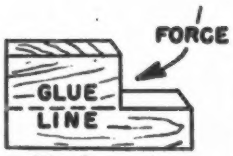


THE NAFM TEST

The University of Michigan Forestry School, in conjunction with the National Association of Furniture Manufacturers, has designed a machine for the making and testing of cross lap glue block specimens that are to be ruptured under tension.

This inexpensively constructed machine is useful in research work for determining gap filling ability, speed of set, assembly time, the effect of clamping pressure and other properties of glues.

Impact Tester



THE IMPACT TEST

Since bowling pins, chairs and other glued articles are often subject to severe impact rather than static loads, the impact strength of an adhesive is often important.

To determine the impact strength of wood adhesives the special machine and specimen as shown are used. Impact values are recorded as the number of foot pounds per square inch required to cause failure of the specimen.

The impact test is fully described as Method D-950-54 of the American Society of Testing Materials.

VII. Strength of glue line on air dried lumber

A. This method of test is intended to compare the strength of glue line between air dried and kiln dried lumber.

B. To conduct the test requires six test blocks, polyvinyl glue, plastic resin glue, and a data sheet.

C. The apparatus shall consist of adhesive shear testing device, clamps, drill press, and bathroom scales.

D. Procedure

1. Select air dried lumber (12 to 15% MC)
2. Cut to size recommended for sample glue blocks.
3. Follow suggested steps in making test blocks. (Allow test blocks to cure 24 hours.)
4. Cut test blocks to suggested size.
5. Label test blocks for identification.
6. Fasten top of shear test apparatus in drill press chuck.
7. Place bathroom scale on drill press table.
8. Position bottom of test apparatus on top of scale.
9. Position test block between upper and lower portion of test apparatus.
10. Check dial on scale to be sure it is located on zero.
11. Apply a slow and steady pull on drill press handle until test block shears. Observe pounds of pressure reading on scale at moment of shear.
12. Record the pounds of pressure on the data sheet.

VIII. The effect of heat and water on plastic resin and resorcinol

A. This method of test is intended to compare the glue line strength of plastic resin and resorcinol glue after the application of heat and water.

B. To conduct the test requires plastic resin glue, resorcinol glue, six glue test blocks and a data sheet.

C. The apparatus shall consist of adhesive shear-testing device, clamps, drill press, bathroom scale, and a hot plate.

D. Procedure

1. Select kiln dried maple.
2. Cut to size recommended for glue test blocks.
3. Follow suggested steps in making test blocks. (allow to cure 24 hours)
4. Label test blocks for identification after cutting to size.
5. Place the six glue test blocks in water. Allow to boil for 30 minutes.
6. Remove blocks from boiling water and allow to dry for 24 hours.
7. Fasten top of shear test apparatus in drill press chuck.
8. Place bathroom scale on drill press table.
9. Position lower portion of test apparatus on top of scale.
10. Position test block between upper and lower portion of test apparatus.
11. Check dial on scale to be sure it is located on zero.
12. Apply a slow and steady pull on drill press handle until the test block shears. Observe pounds of pressure reading on scale at moment of shear.
13. Record pounds of pressure on data sheet.

I X. Comparison of holding power between polyvinyl and plastic resin glue, using a brief curing time.

A. This method of test is intended to test the difference in pull needed to separate by hand two test blocks fastened with different glues after a thirty minute setting time.

B. To conduct the test, you will need 4 pieces of 2" x 2" x 3/4" maple blocks, polyvinyl glue, plastic resin glue, and a data sheet.

C. The apparatus shall consist of clamps of sufficient size.

D. Procedure

1. Select kiln dried 3/4" maple (6% M C)
2. Cut twelve 2" x 2" x 3/4" blocks.
3. Apply polyvinyl glue to the face of six blocks and plastic resin to the others.
4. Clamp the blocks together for thirty minutes.
5. Label the blocks.
6. After thirty minutes, remove the clamps.
7. Attempt to pull the blocks apart by hand.
8. Run three tests for each adhesive.
9. Record the findings on data sheet.

X. Strength of glue line on wood to metal

A. This method of test is intended to check the holding power of wood to metal with epoxy resin glue.

B. To conduct the test you will need six test blocks of wood and six of metal epoxy, resin glue and a data sheet.

C. The apparatus shall consist of adhesive shear testing device, clamps, drill press, bathroom scale.

D. Procedure

1. Cut metal to size recommended for sample specimens.
2. Cut lumber to size.
3. Glue lumber to metal blocks.
4. Let cure for 24 hours.
5. Label blocks for identification.
6. Fasten tip of jig in drill press chuck.

7. Place bathroom scales on drill table.

8. Position bottom of test jig on top of scale.

9. Check dial on scale to be sure it is located on zero.

10. Apply a slow and even pull on drill press handle until test block shears. Observe pounds of pressure reading on scale at moment of shear.

11. Record pounds of pressure on data sheet.

XI. Glue film stretch test

A. This method of test is intended to test the effect of temperature on various adhesive film strips.

B. To conduct the test requires polyvinyl glue, aliphatic glue, plastic resin, and a data sheet.

C. The apparatus shall consist of glue film apparatus and glass or teflon surface.

D. Procedure

1. Make two .05" x 4" long films from each of the types of glue listed above.

2. Mount each sample on a piece of 8 1/2 x 11 paper with a paper clip and label each sample on the paper. (allow to cure for 24 hours)

3. Take one sample at a time and place it between the palms of your hands and keep a firm pressure on it for 30 seconds.

4. After the 30 seconds have elapsed, grip the glue film at each end and pull with a slow even pressure until the film appears to weaken.

5. Measure each film after pulling to record amount of elongation.

6. Record findings on data sheet.

XII. Specimen Data Sheet

A. Date

B. Sample number

C. Type of adhesive

D. Species of wood

E. Moisture condition

F. Open assembly time in minutes

G. Curing time

H. Length of time specimen has been glued

I. Room temperature

J. Relative humidity in the room

K. Load at moment of failure in pounds

L. Maximum stress in shear $V=\frac{P}{A}$ in pounds per square inch.

M. Per cent of glue failure

N. Per cent of wood failure

O. Procedure used (by name or number)

P. Number of cycles to which specimen was subjected.

Q. The pH of the distilled water

R. Temperature of the bath

S. Type of failure

T. Extent of failure

GLOSSARY

1. Adherend - The material being joined by the adhesive.

2. Adhesive - A substance which will bond together the contacting materials by surface attraction.

3. Ambient atmosphere - The surrounding or encompassing atmosphere.

4. Assembly - The application of the adhesive to the parts and the collection and arrangement of these parts in holding or clamping devices where they remain until sufficiently set.

5. Assembly time - That time between the spreading of the adhesive and the application of pressure, heat or both to the assembly. It is composed of both open and closed assembly time. Open assembly time ends when the aprts are brought into contact with each other. Closed assembly time starts immediately and lasts until pressure and/or heat is applied.

6. Bonding - The joining together of materials with adhesives.

7. Catalyst - Substance which starts and/or speeds up a chemical reaction in an adhesive. This reaction results in curing of the adhesive and bonding of the materials.

8. Cohesion - The resistance of a material to separation, as the cohesive strength of the adhesive itself.

9. Crazing - Fine cracks which may extend in a fine network on or under the surface of a layer of adhesive.

10. Curing time - The time needed for an adhesive bond to attain its full strength. (Chemical Reaction)

11. Delamination - The separation of layers in a laminate because of failure of the adhesive.

12. Drying Time - The time needed for an adhesive bond to attain its full strength. (Evaporative Action)

13. Durability - The life of the adhesive in providing a structually sound bond.

14. Equilibrium Moisture Content - The moisture content of wood after it has become balanced with the surrounding atmospheric humidity. It is expressed as a percentage of the oven-dry weight of the wood.

15. Extender - A substance, usually having some adhesive action, added to an adhesive to reduce the amount of primary binder required per unit area.

16. Filler - A relatively non-adhesive substance added to an adhesive to improve its working properties.

17. Harden - See Setting Time.

18. Hardener - Substance or mixture of substances added to an adhesive to promote or control curing action.

19. Laminating - The bonding together of several layers of materials.

20. Modifier - Any chemically inert ingredient added to an adhesive mixture which changes its properties.

21. Plasticizer - A material added to an adhesive to increase its flexibility, workability or distensibility.

22. Relative humidity - The ratio of actual moisture in the atmosphere to the maximum possible at the existing temperature, expressed as a percentage.

23. Setting Time - The time needed for an adhesive bond to attain sufficient strength so that the pressure may be removed from the assembly.

24. Spread - The amount of adhesive per unit of area to which it is applied. The spread may be to one surface (single) or to both surfaces (double).

25. Squeezeout - The adhesive extruded from the glue line when pressure is applied. It is sometimes called the exudate.

26. Starved joint - Glue line with too little adhesive remaining between the interfaces.

27. Storage life - The life of the packaged adhesive in storage (shelf life).

28. Synthetic - Man made raw materials.

29. Tack - A condition which exists after an adhesive has been applied and before it has set. Usually sticky to the touch.

30. Thermoplastic - A material which will repeatedly soften when heated and harden when cooled.

31. Thermosetting - A material which undergoes a chemical reaction when is applied and then becomes relatively infusible.

32. Wood failure - The tearing of wood fibers at the glue line when a joint is broken.

33. Working life - The time a glue mix remains usuable (pot life).

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Appendix

Glues and Adhesives

American Cyanamid Company
Wallingford
Connecticut 06492

Armour Coated Products & Adhesives
430 N. Michigan
Chicago, Illinois 60611

B. B. Chemical Company
784 Memorial Drive
Cambridge, Massachusetts 02141

The Borden Company
Chemical Division
350 Madison Avenue
New York, N. Y. 10017

Catalin Corporation of America
1 Park Avenue
New York, N. Y. 10016

Peter Cooper Corporations
Gowanda
New York 14070

Devcon Corporation
Danvers
Massachusetts 01923

Formica Corporation
4615 Spring Grove Avenue
Cincinnati, Ohio 45232

Franklin Glue Company
2020 Bruck Street
Columbus, Ohio 43207

H. B. Fuller Company
1150 Eustis Street
St. Paul, Minnesota 51108

Koppers Company
Tar and Chemical Division
Pittsburg, Pennsylvania 15230

Macco Chemical Company
Division of the Glidden Company
900 Union Commerce Building
Cleveland, Ohio 44115

Minnesota Mining & Mfg. Company
2501 Hudson Road
St. Paul, Minnesota 55119

Monite Waterproof Glue Company
1628 N. Second Street
Minneapolis 11, Minnesota 55405

Monsanto Chemical Company
9229 E. Marginal Way South
Seattle, Washington 98108

National Casein Company
601 W. 80th Street
Chicago, Illinois 60620

National Starch & Chemical Company
National Adhesives Division
750 Third Avenue
New York, New York 10017

Paisley Products Division
International Latex & Chemical Corporation
1153 Bloomfield Avenue
Clifton, New Jersey 07012

Perkins Glue Company
Lansdale
Pennsylvania 19446

Pittsburgh Plate Glass Company
Adhesives Division
225 Belleville Avenue
Bloomfield, New Jersey 07003

Reichhold Chemicals Inc.
525 N. Broadway
White Plains, New York 10601

Rohn & Haas Company
Washington Square
Philadelphia 5, Pennsylvania 19106

Swift & Company
Adhesive Products Department
115 W. Jackson Blvd.
Chicago, Illinois 60604

Synco Resins, Inc.
Bethel
Connecticut 06801

U.S. Plywood Corporation
777 Third Avenue
New York, New York 10017

U.S. Rubber Company
Adhesives & Coatings Department
Mishawaka, Indiana 46544